Better Buildings Residential Network Peer Exchange Call Series

Behavior Change, Efficiency and Climate: What Really Happens vs. Models & Assumptions?

September 9, 2021

Agenda and Ground Rules

- Agenda Review and Ground Rules
- Opening Poll
- Residential Network Overview and Upcoming Call Schedule
- Featured Speakers
  - **Aven Malloy, Lawrence Berkley National Laboratory**
  - **David Siddiqui, Oracel**
  - **Reuven Sussman, ACEEE**
- Open Discussion
- Closing Poll and Announcements

Ground Rules:

1. **Sales of services and commercial messages are not appropriate** during Peer Exchange Calls.
2. Calls are a safe place for discussion; **please do not attribute information to individuals** on the call.

The views expressed by speakers are their own, and do not reflect those of the Dept. of Energy.

Better Buildings Residential Network

Join the Network

Member Benefits:

- Recognition in media and publications
- Speaking opportunities
- Updates on latest trends
- Voluntary member initiatives
- One-on-One brainstorming conversations

Commitment:

- Members only need to provide *one number*: their organization's number of residential energy upgrades per year, or equivalent.

Upcoming Calls (2nd & 4th Thursdays):

- *9/23: EMERGENCY Replacements – The Biggest Real-World Obstacle to Efficiency?*
- *10/14: Remodeling – The Biggest Untapped Efficiency Opportunity?*

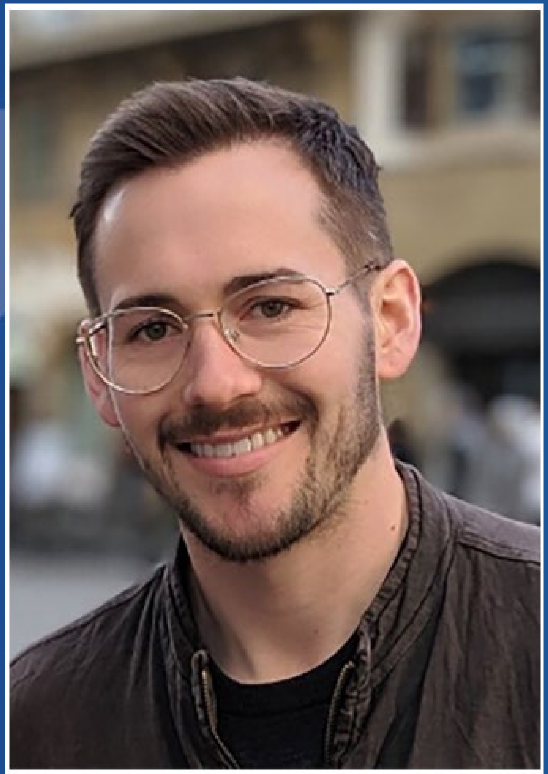
Peer Exchange Call summaries are posted on the Better Buildings website a few weeks after the call

For more information or to join, for no cost, email bbresidentialnetwork@ee.doe.gov, *or go to* energy.gov/eere/bbrn & *click Join*

Call Attendee Locations

Opening Poll

- What is your organization's experience or familiarity with the relationship between behavior change, efficiency, and climate?
  - Very experienced/familiar
  - Some experience/familiar
  - Limited experience/familiar
  - No experience/familiar
  - Not applicable



Aven Meloy

Lawrence Berkeley National Laboratory

Modeling and Measuring Efficiency and Flexibility at the National and Household Scales

Q:\EE-5B\BETTER BUILDINGS\Program management\Network (BBRN)\PROGRAMMING\PEER EXCHANGE CALLS\SCHEDULE

Aven Satre-Meloy, PhD

Building Technology and Urban Systems Division,
Lawrence Berkeley National Laboratory

BBRN Webinar: Behavior Change, Efficiency and Climate - What Really Happens vs. Models & Assumptions

September 9, 2021

BERKELEY LAB

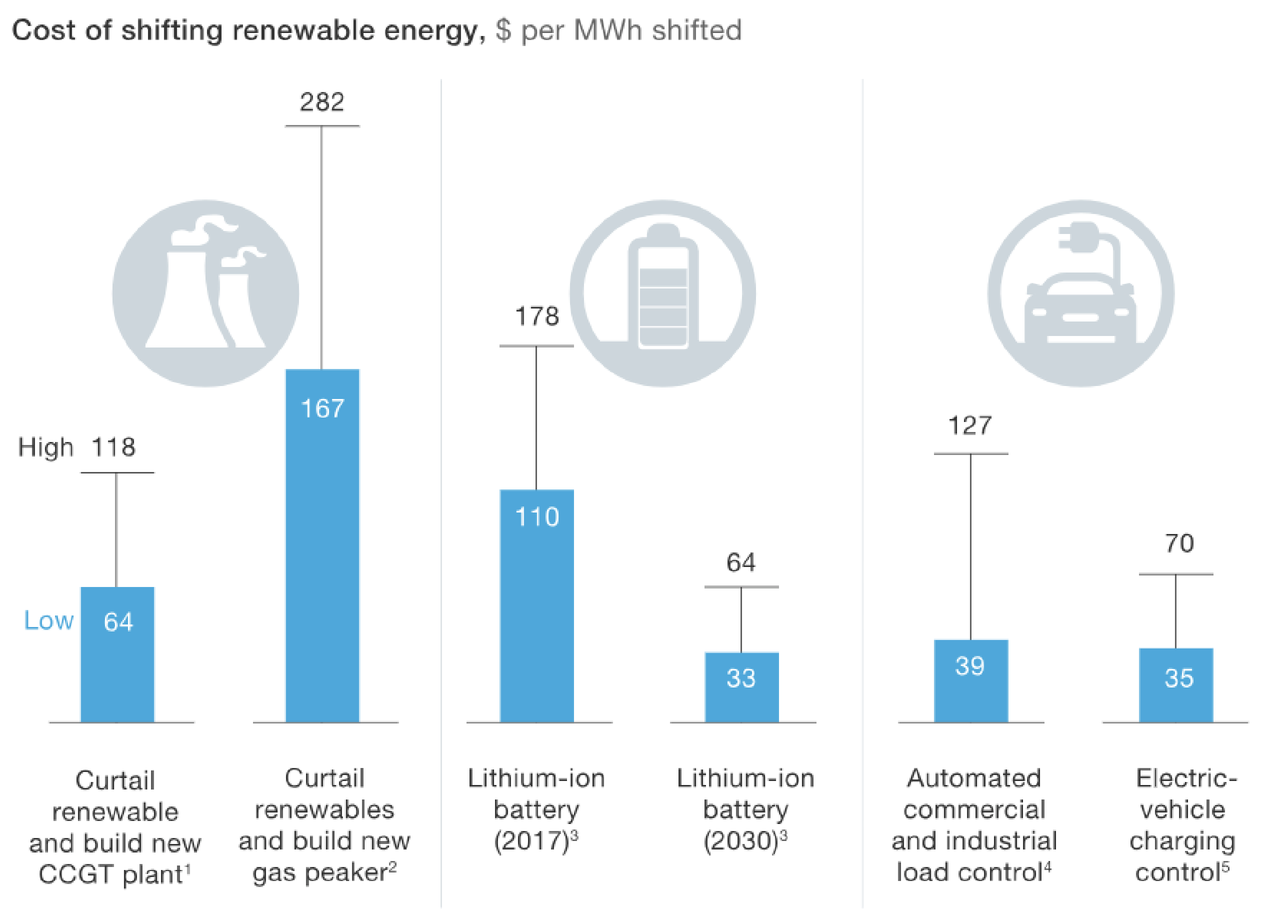
Acknowledgements

- National lab/DOE collaborators:
  - LBNL: Jared Langevin, Handi Putra, Andy Satchwell
  - NREL: Chioke Harris, Andrew Speake, Elaina Present, Rajendra Adhikari, Eric Wilson
  - Monica Neukomm, David Nemtzow and Karma Sawyer, U.S. DOE Building Technologies Office
  - Laura Martin, U.S. Energy Information Administration
- University of Oxford collaborators:
  - Philipp Grünewald and Marina Diakonova, University of Oxford

Modeling the impact of efficiency and flexibility measures at the regional and national scales

Research question: What is the available grid "resource" from buildings in the U.S., and how does it vary temporally and geographically?

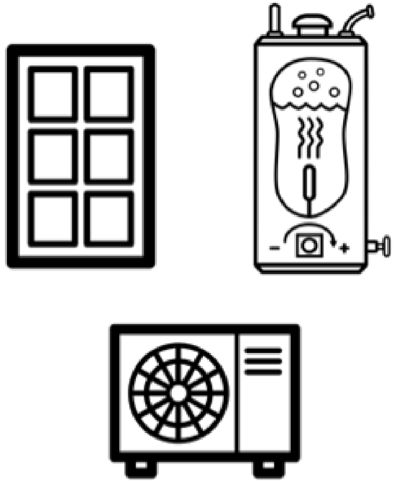
- Buildings comprise 75% of U.S. electricity demand, and demand-side flexibility can support variable renewable electricity penetration cost-effectively.
- The magnitude of the potential grid resource from energy efficient and flexible buildings has not been quantified for a realistic set of emerging building technologies and operational approaches.

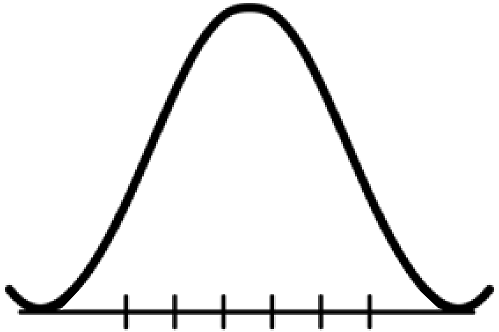


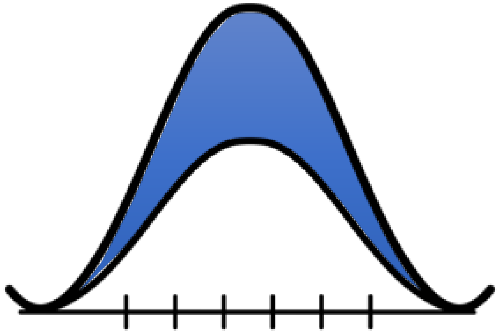
Comparison of the costs per MWh of shifting renewable energy from generation sources, and battery storage/distributed energy resources. Aggregated demand-side flexibility resources are found to be cost-effective and frequently cheaper than the generation alternative. Source: McKinsey.

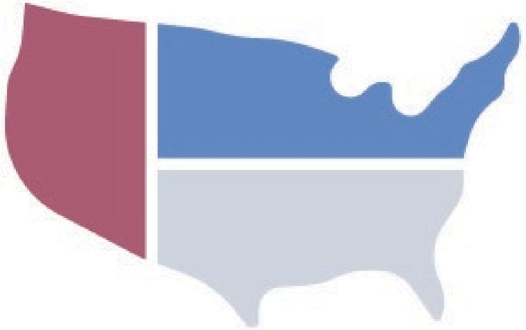
A quantitative framework for modeling the time- and location-sensitive value of building efficiency/flexibility is developed

1. Define energy efficiency (EE), demand flexibility* (DF), and EE + DF measure portfolios
2. Develop 8760 hourly fractions of annual baseline load by climate, building type, and end use
3. Develop bottom-up EnergyPlus measure simulations and 8760 savings fractions based on regional system needs
4. Translate measures to Scout and assess regional/national portfolio potential, annually and sub-annually (2015-2050)



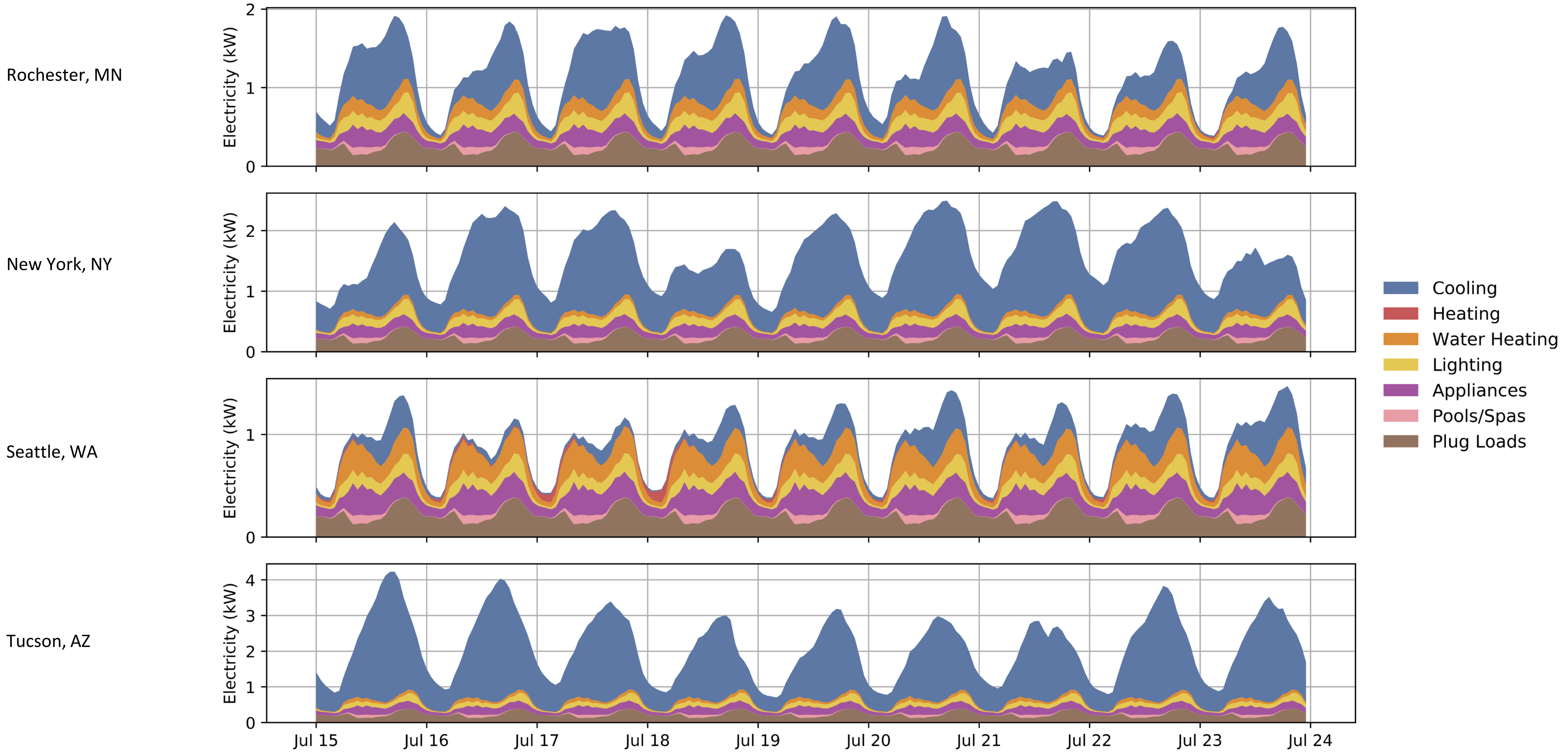






* “Flexibility” measures can reduce load during peak hours (“shed”) or move electricity use out of the peak period (“shift”). Further details on demand flexibility can be found in the Building Technologies Office Grid-interactive Efficient Buildings Overview.

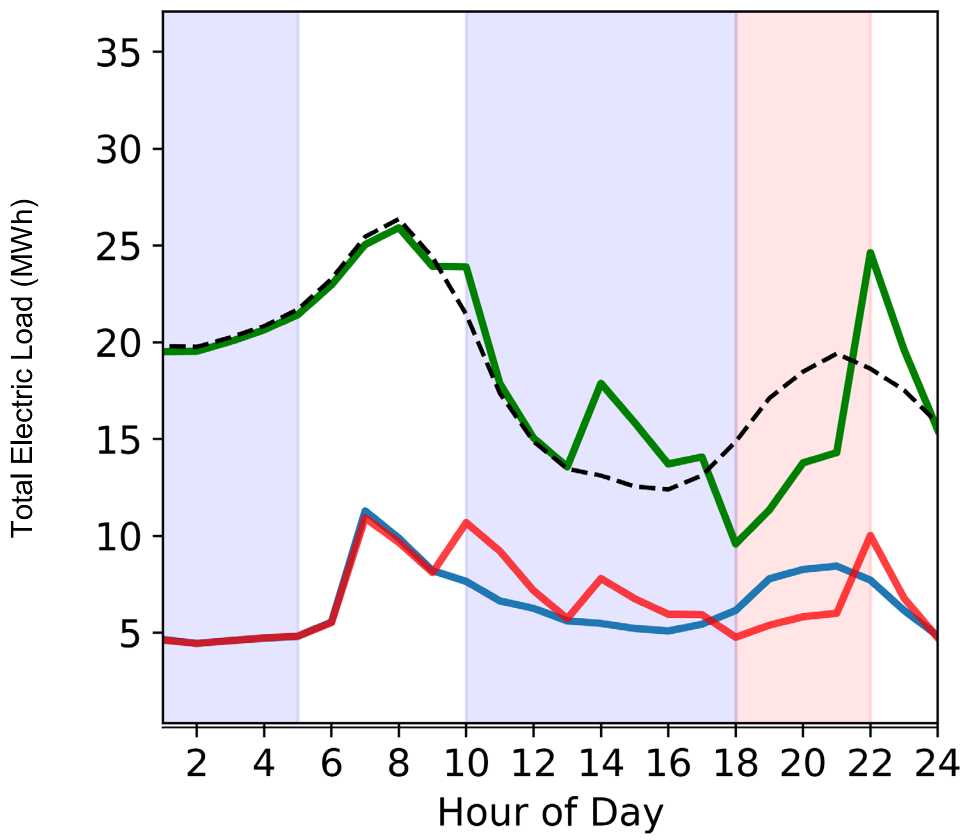
Example baseline residential load shapes (summer)



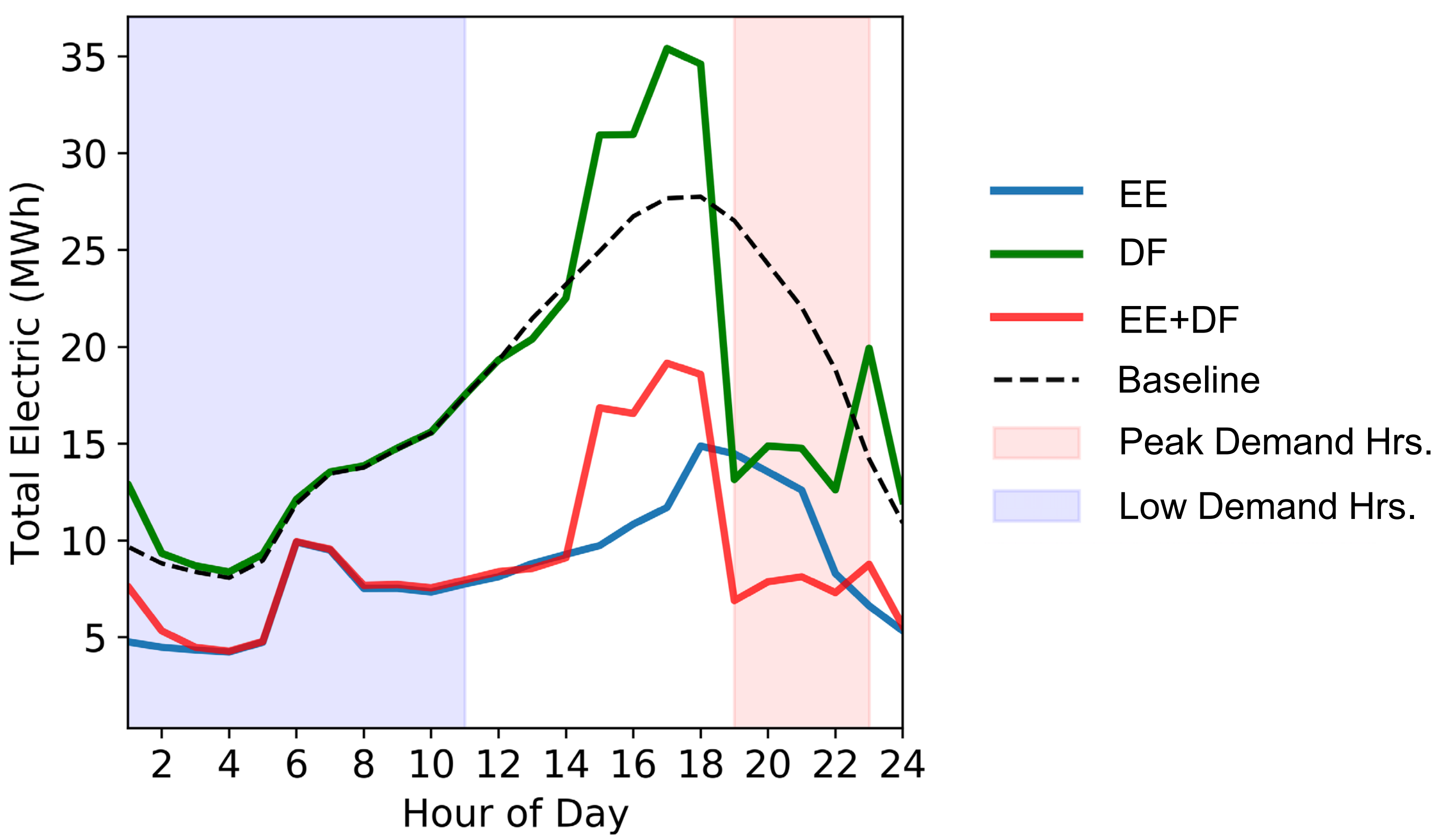
Data: ResStock

Flexibility measures reduce load on-peak and build load off-peak, while efficiency measures reduce load across all hours

Atlanta (3A) – January 24, Residential

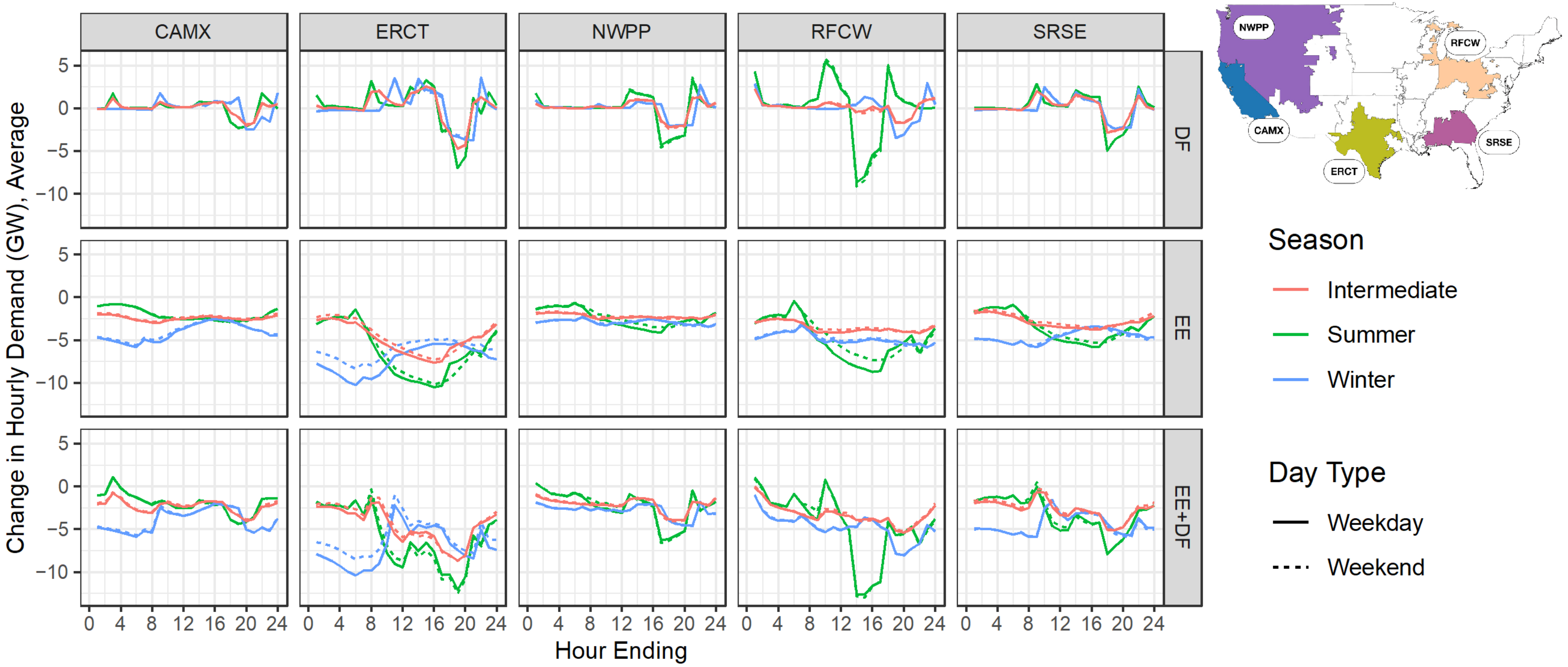


Atlanta (3A) – August 24, Residential



Langevin et al., 2021

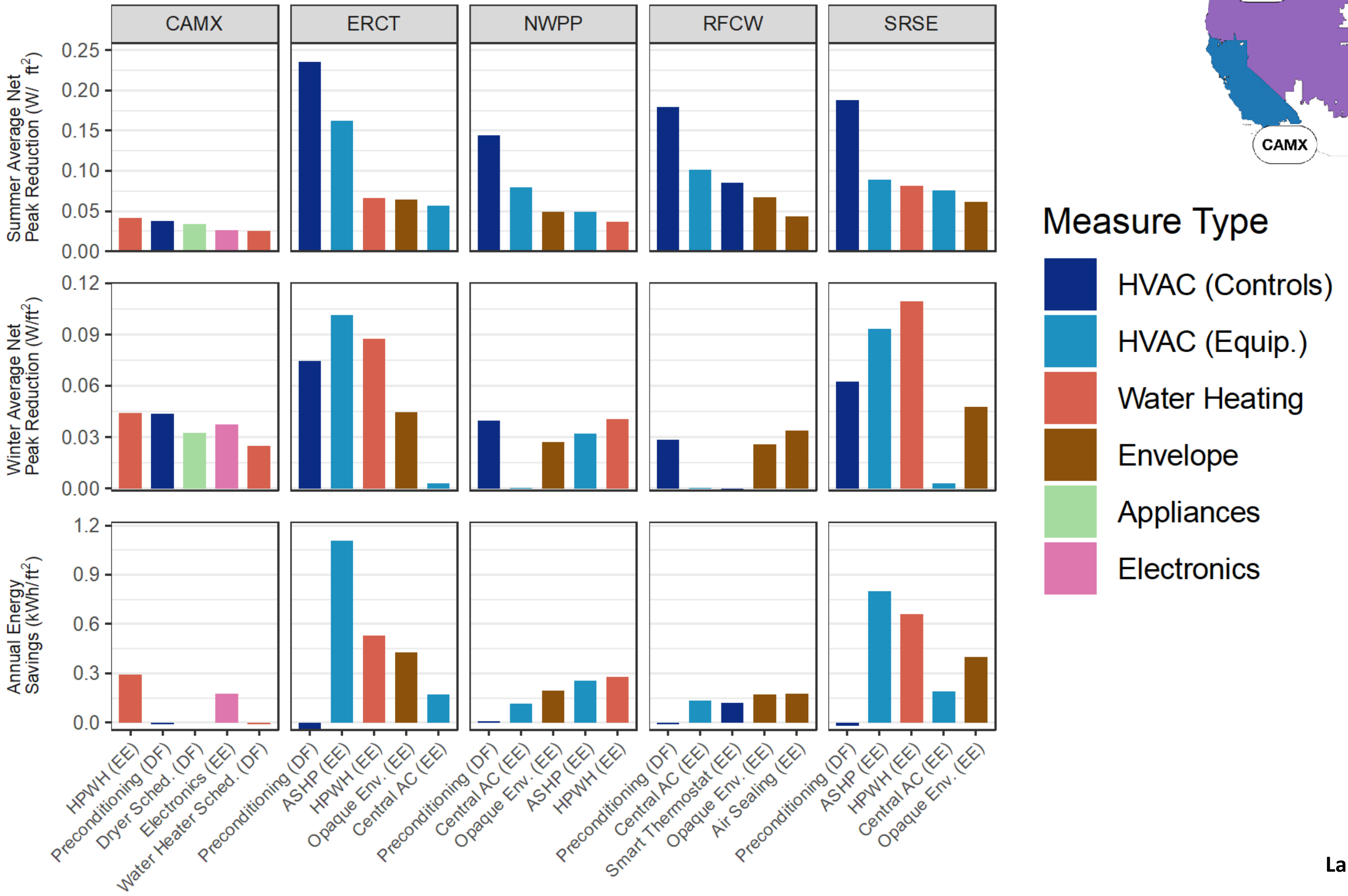
Changes in hourly demand across regions and seasons are most pronounced in measure sets that include efficiency (EE, EE+DF)

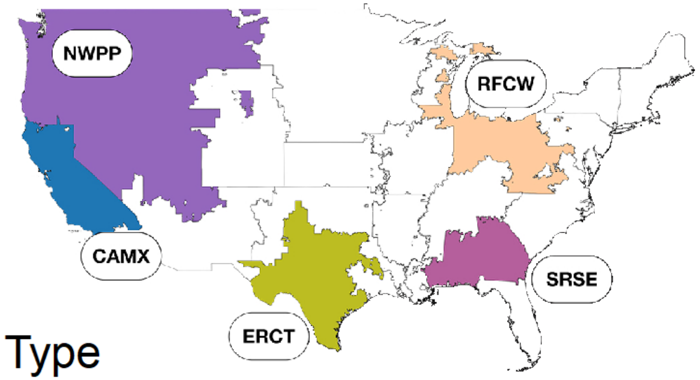


Langevin et al., 2021

Residential preconditioning and heat pump water heaters have the largest impacts on electricity demand

Individual measures with the largest summer net peak demand intensity reductions in 2030 for five U.S. grid regions

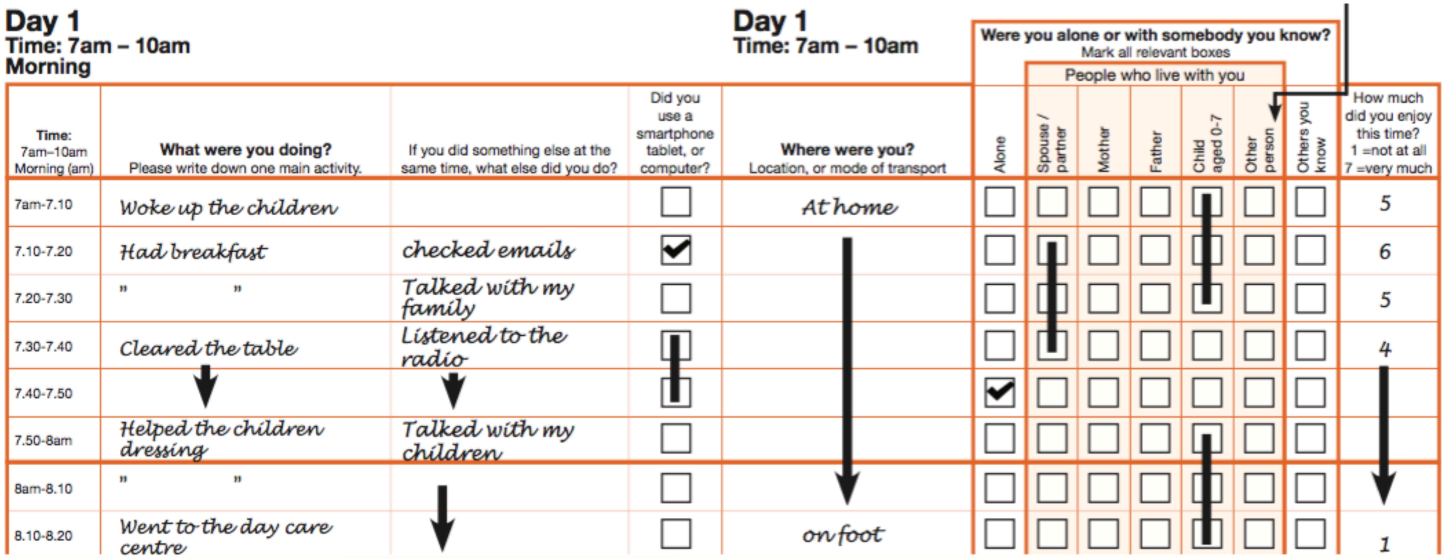




Langevin et al., 2021

Measuring the relationship between activities and electricity demand at the household scale

Measuring and Evaluating Time- and Energy-use relationships (METER)



Day 1
Time: 7am – 10am
Morning

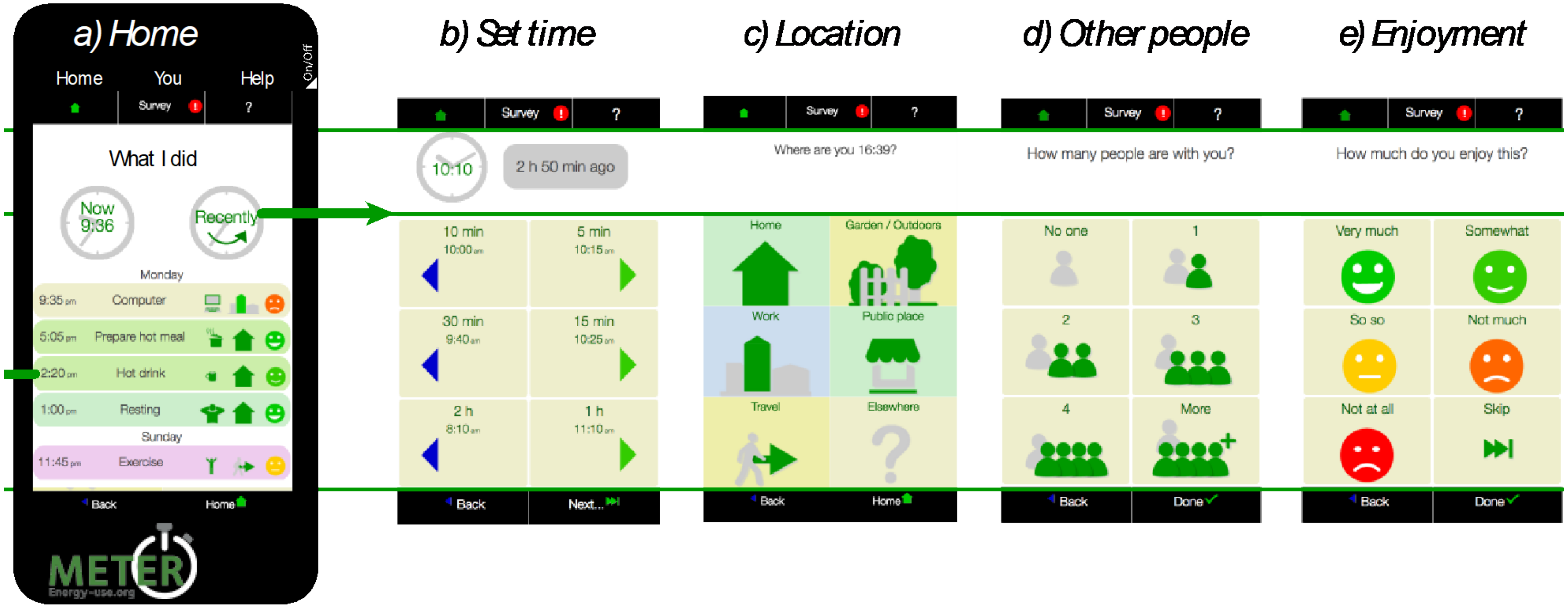
Day 1
Time: 7am – 10am

Time: 7am–10am Morning (am)	What were you doing? Please write down one main activity.	If you did something else at the same time, what else did you do?	Did you use a smartphone tablet, or computer?	Where were you? Location, or mode of transport	Were you alone or with somebody you know? Mark all relevant boxes: Alone	People who live with you: Spouse / partner	Mother	Father	Child aged 0-7	Other person	Others you know	How much did you enjoy this time? 1 =not at all 7 =very much
7am-7.10	Woke up the children			At home								5
7.10-7.20	Had breakfast	checked emails	✓									6
7.20-7.30	" "	Talked with my family										5
7.30-7.40	Cleared the table	Listened to the radio										4
7.40-7.50					✓							
7.50-8am	Helped the children dressing	Talked with my children										
8am-8.10	" "											
8.10-8.20	Went to the day care centre			on foot								1

METER Energy-use.org

EPSRC Engineering and Physical Sciences Research Council

Grunewald & Diakonova, 2018

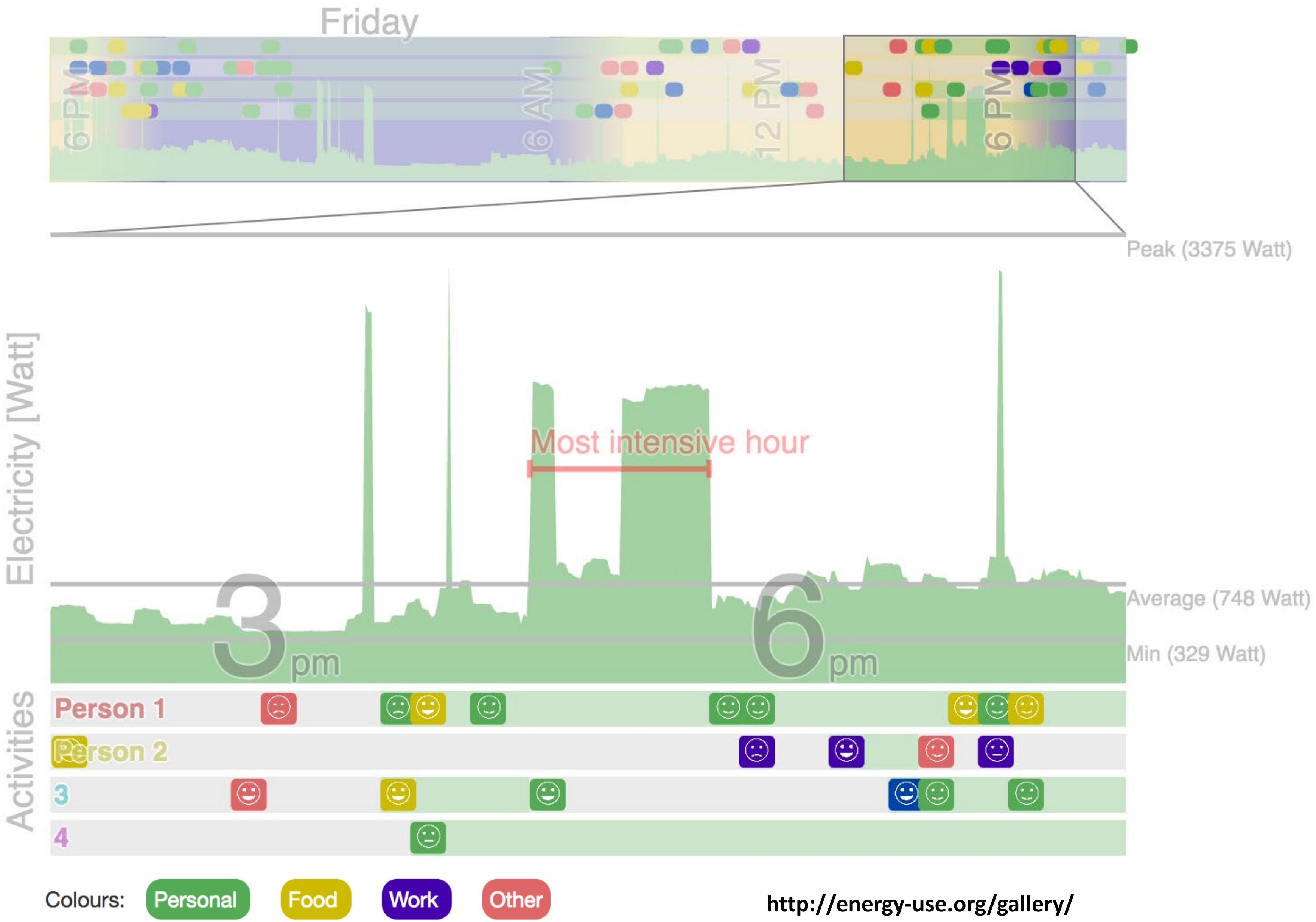


Location	Activity				Other people	Enjoyment
Home	Personal	Next…	Cold meal	Next…	No one	Very much
Outdoors	Joint	Prepare	Hot meal	Oven	1	Somewhat
Work	Work	Lay of clear	Baking	Hob	2	So so
Public Place	Food	Eat	Lay table	Microwave	3	Not much
Travel	Appliances	Snack		Kettle	4	Not at all
Elsewhere	Customise	Hot drink	Next…	Toaster	More	Skip

3 selections → discriminate 216 options (…1,296…)

Grunewald & Diakonova, 2018

Sample household electricity profile



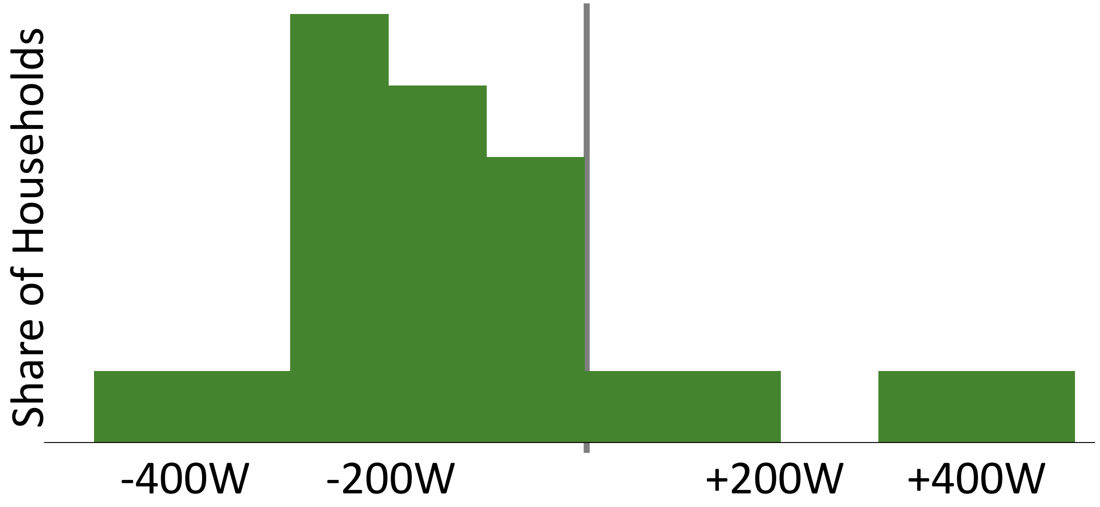
http://energy-use.org/gallery/

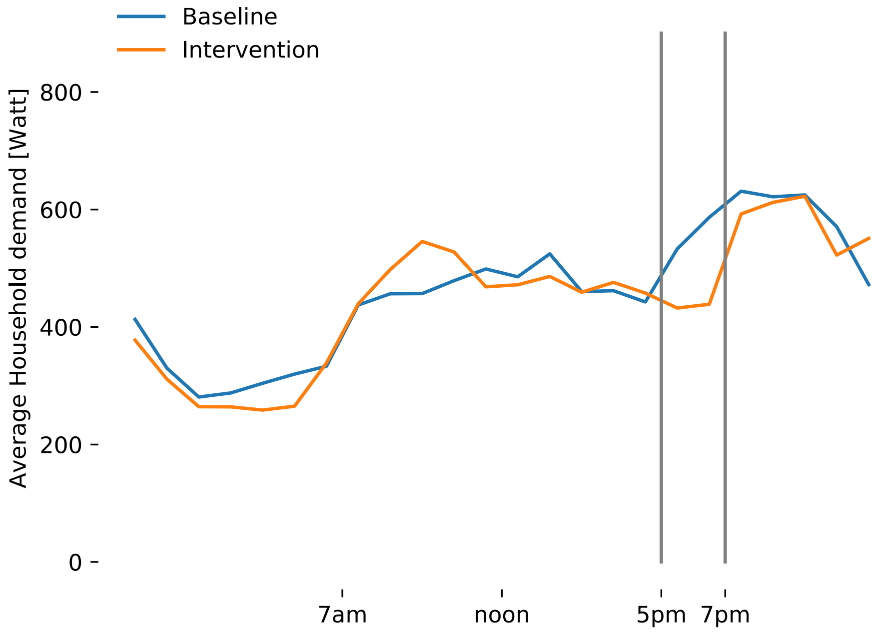
Results of intervention to encourage demand reduction/shifting

Monday 5pm - 7pm

Try to use less electricity from 5pm to 7pm on Monday. This is where you are competing with other streets in the neighbourhood. Things to avoid might be:
dish washers, washing machines, electric cookers, etc.

Good luck.

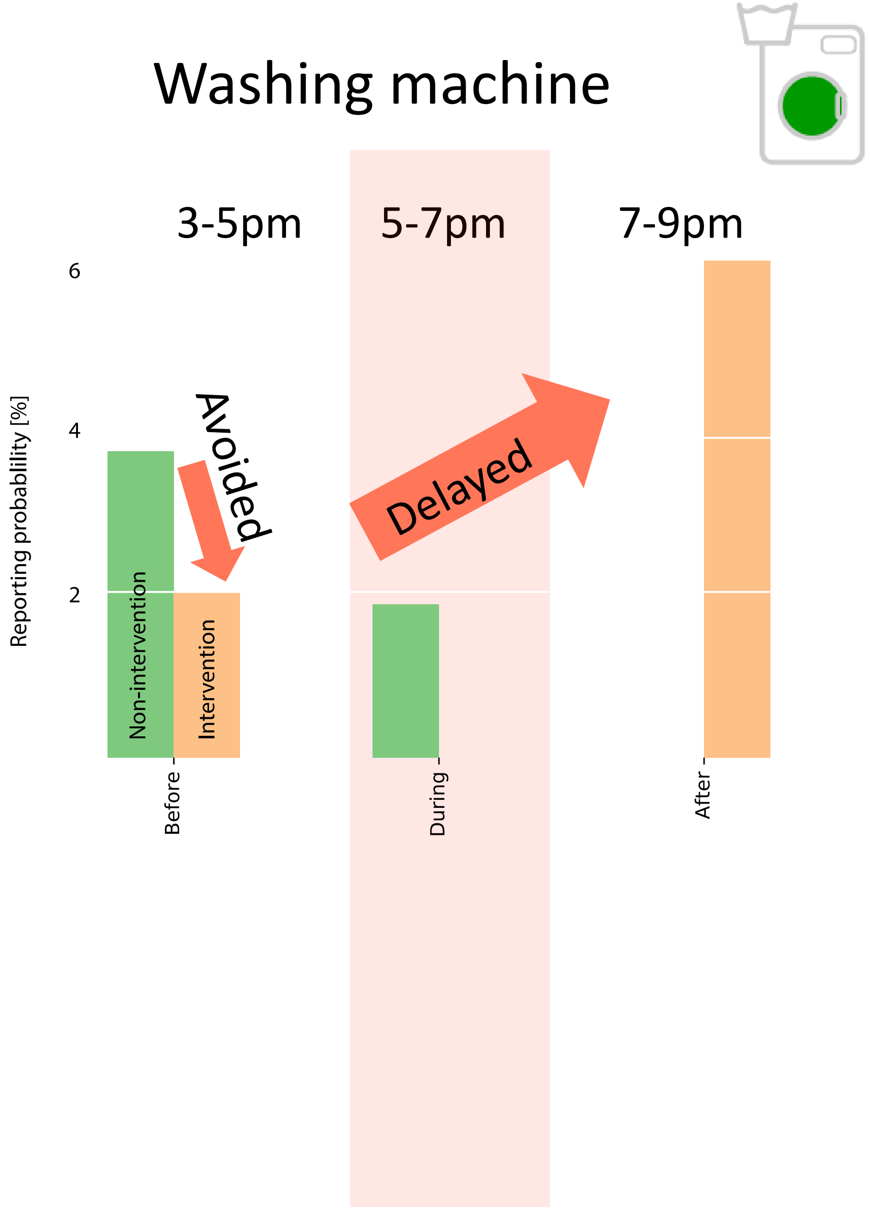


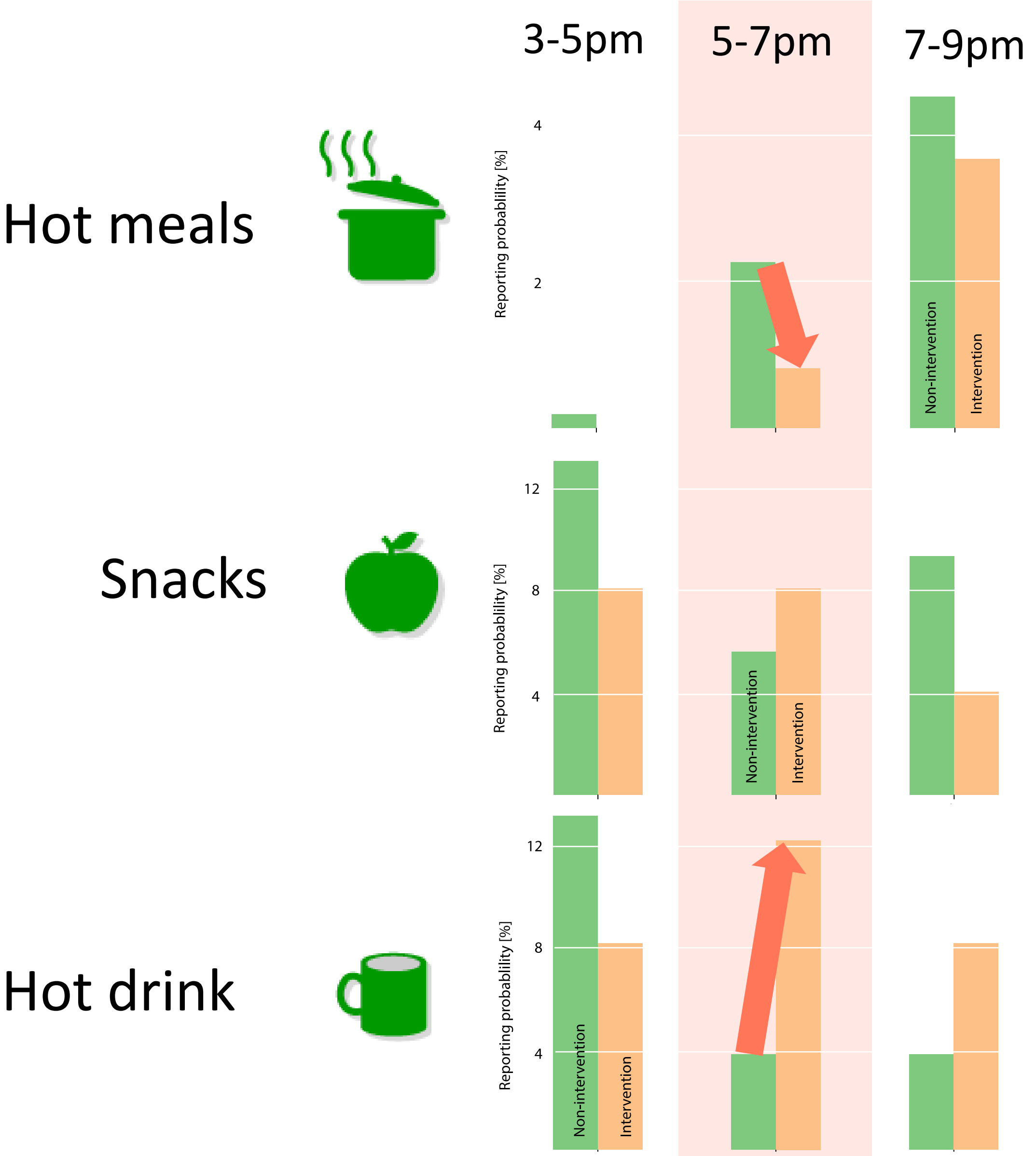


14% avg reduction in peak load

Environmental Change Institute

Evidence on the activities underpinning demand response





Activities occupants are willing-to-shift may not match model assumptions

Stelmach, et al. 2020

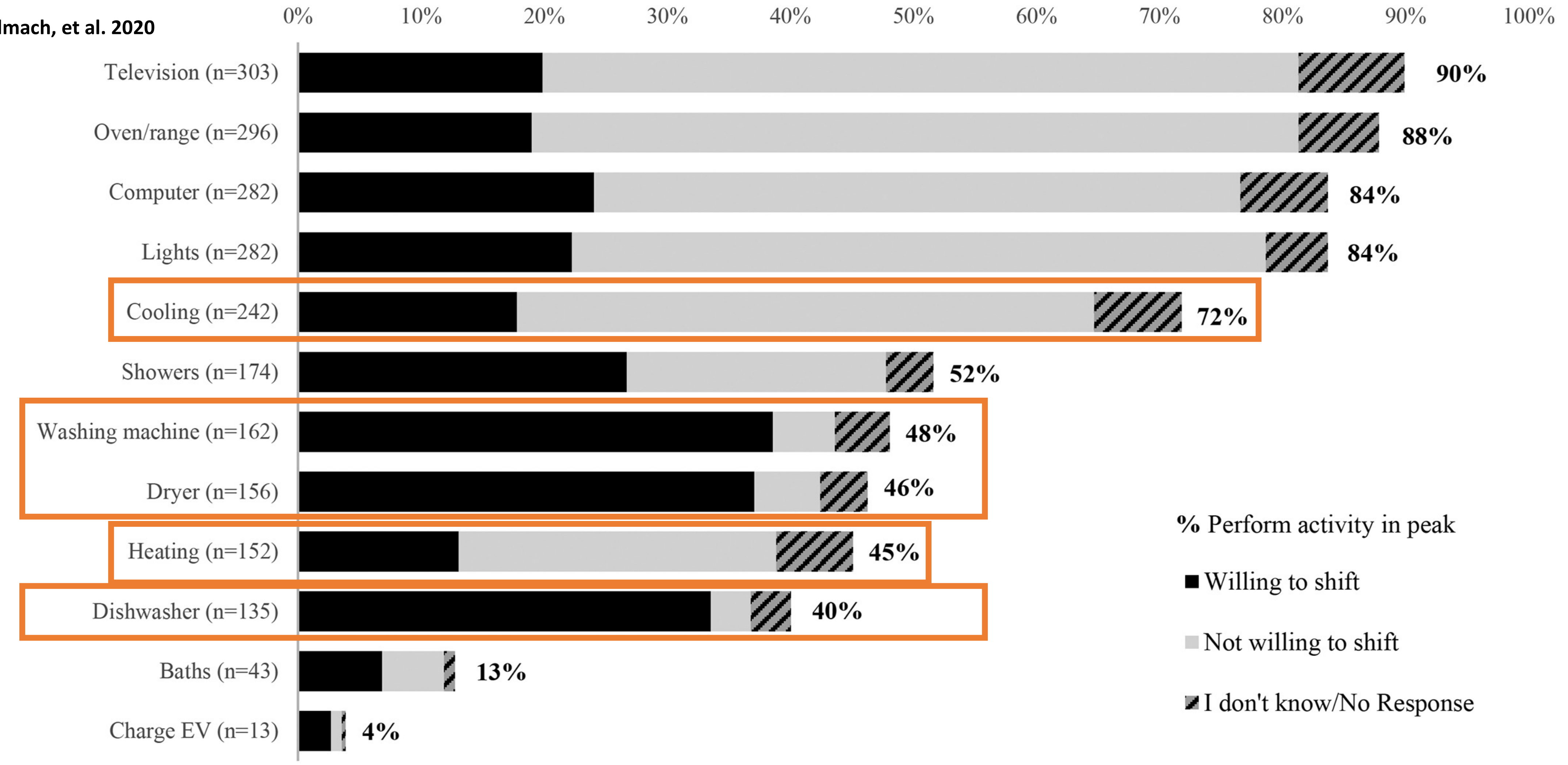


Fig. 2. **Activity frequencies in peak and willingness-to-shift given 30% price increase.** Overall bar represents the proportion of respondents who reported performing the activity in peak (e.g., 90% reported watching television in peak). Darker shading represents the relative proportion of respondents reporting this activity who were also willing to shift it out of peak given a 30% price increase.

Conclusions and implications

Modeled results show a large potential peak reduction resource from buildings

- Residential cooling and heating show large potential for impacts on electricity demand

Evidence from time-use research and field studies of household demand response interventions suggest modeled results may not hold in the real world

- Other activities have strong coincidence with peak demand and may be better targets for interventions
- Willingness-to-shift is lower for heating/cooling activities than for other appliances (washing/drying, dishwashing)
- More evidence on the links between activities/behaviors and energy use in households is necessary to improve models (e.g., validation of load profiles and savings shapes) and bring "what really happens" closer to what models assume

* EIA AEO 2019 data, after accounting for T&D losses

References & related work

- Grunewald, P., Diakonova, M., 2018. The electricity footprint of household activities–implications for demand models. Energy and Buildings 174, 635–641. https://doi.org/10.1016/j.enbuild.2018.06.034
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- Satre-Meloy, A., Diakonova, M., Grünewald, P., 2019. Daily life and demand: An analysis of intra-day variations in residential electricity consumption with time-use data. Energy Efficiency 1–26. https://doi.org/10.1007/s12053-019-09791-1
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- Satre-Meloy, A., Langevin, J., 2019. Assessing the time-sensitive impacts of energy efficiency and flexibility in the US building sector. Environ. Res. Lett. 14, 124012. https://doi.org/10.1088/1748-9326/ab512e
- Stelmach, G., Zanocco, C., Flora, J., Rajagopal, R., Boudet, H.S., 2020. Exploring household energy rules and activities during peak demand to better determine potential responsiveness to time-of-use pricing. Energy Policy 144, 111608. https://doi.org/10.1016/j.enpol.2020.111608

Thank you – questions?

Aven Satre-Meloy, asatremeloy@lbl.gov

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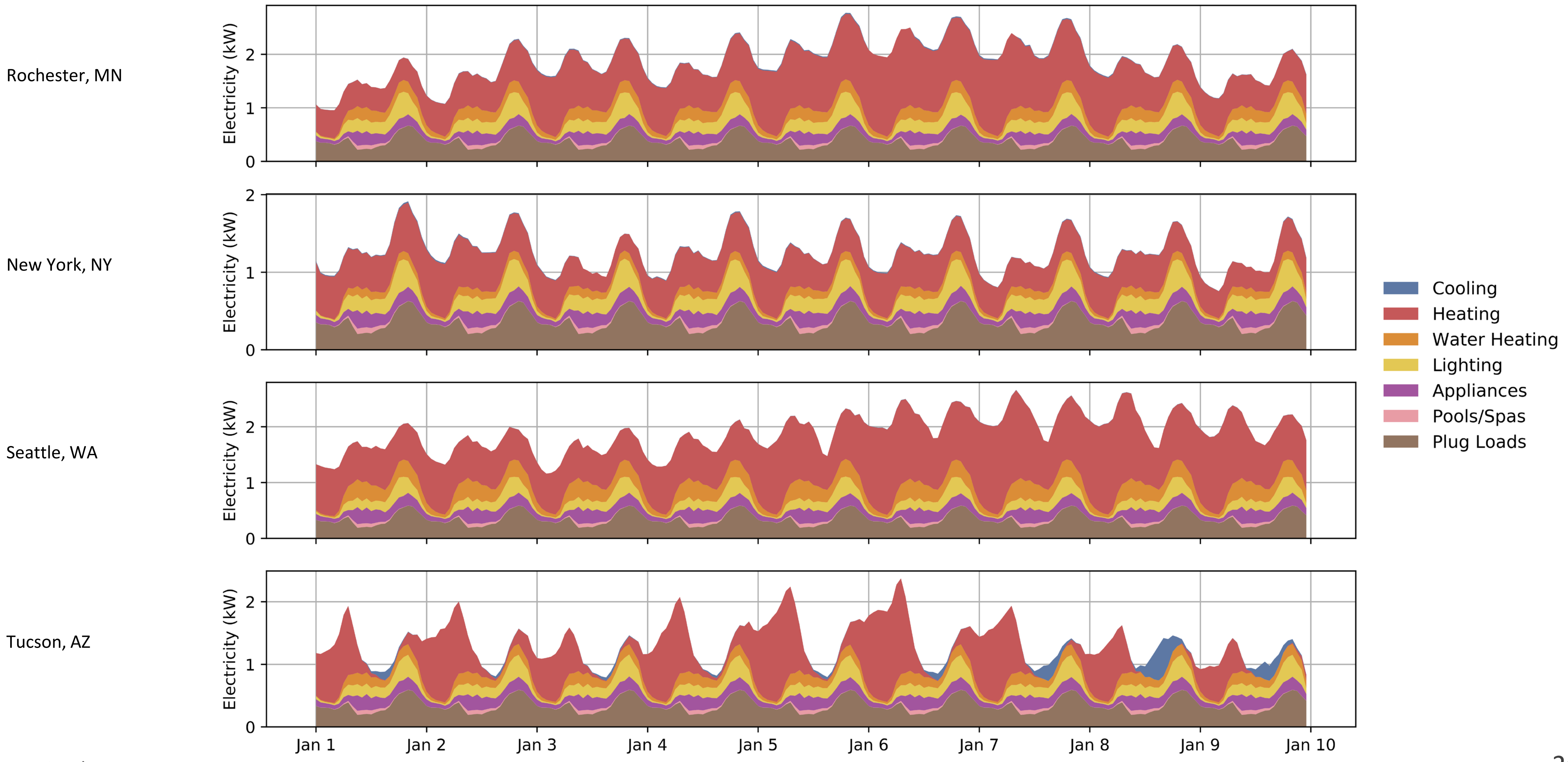
Example baseline residential load shapes (winter)



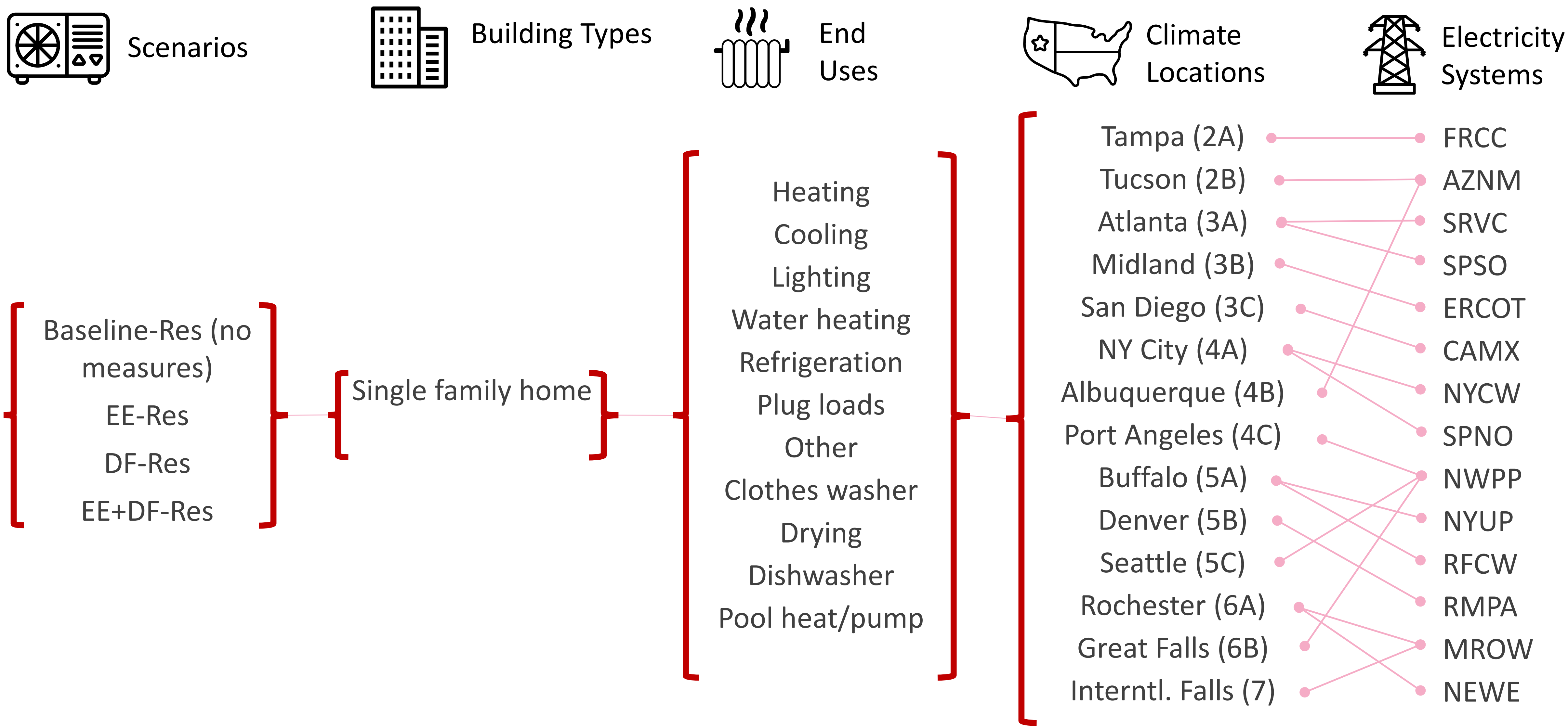
Data: ResStock

Residential EE and DF measures: key assumptions

EE Measure	Approach
Central AC	Upgrade to SEER 18 AC from any lower SEER.
ASHP	Upgrade to SEER 22/HSPF 10 from any lower ASHP, or (in some cases) electric furnaces.
Thermostat controls	Applied 10 hour daytime set-back of 8°F in winter and set-up of 7°F in summer, and 8 hour nighttime set-back of 8°F in winter and 4°F in summer. Daytime set-back only weekdays for 43% of homes.
Refrigerator	Upgrade to EF 22.2.
Walls	Upgrade to R-13 cavity with R-20 external XPS.
Roofs	Upgrade unfinished attic insulation to R-49.
Air sealing	Upgrade to 1 ACH_{50} with mechanical ventilation.
Windows	Upgrade to: U-0.17, 0.49 SHGC in AIA CZ1; U-0.17, 0.42 SHGC in AIA CZ2; U-0.17, 0.27 SHGC in AIA CZ3; U-0.17, 0.25 SHGC in AIA CZ4–5.
Floors	Upgrade wall and ceiling insulation.
HPWH	Upgrade to high EF, 80-gal HPWH.
Clothes washer	Upgrade to IMEF 2.92, usage level maintained.
Clothes dryer	Upgrade to CEF 3.65, usage level maintained.
Dishwasher	Upgrade to 199 rated annual kWh, usage maintained.
Pool pump	Upgrade to (0.75 hp) 1688 rated annual kWh.
Electronics	Decrease total annual energy use by 50%.

DF Measure	Approach
Water heater	Pre-heat to 140°F during take period (second take period, if applicable), then return to 125°F setpoint.
Thermostat	Pre-cool/pre-heat by 3°F starting 4 hours before the peak, then set-back/set-up of 4°F relative to original setpoint during peak period. Thermostat DR setpoints take precedence over EE thermostat setpoints.
Clothes washer, Clothes dryer, Dishwasher	Baseline schedules are generated as normal (randomly based on distributions). Then event clusters during peak are shifted after peak if possible, if not then before peak if possible, if not then left as-is. No change in total energy use.
Pool pump	All energy use during peak period is removed and added uniformly to energy use during the (first) take period. No change in total energy use.
Electronics	Of peak period electronics energy usage: • 11% is shifted to the 2 hour period following the peak, representing discharging batteries during peak. • 4% is removed, representing zero standby power consumption (i.e., advanced power strip controls). Total energy use decreases.

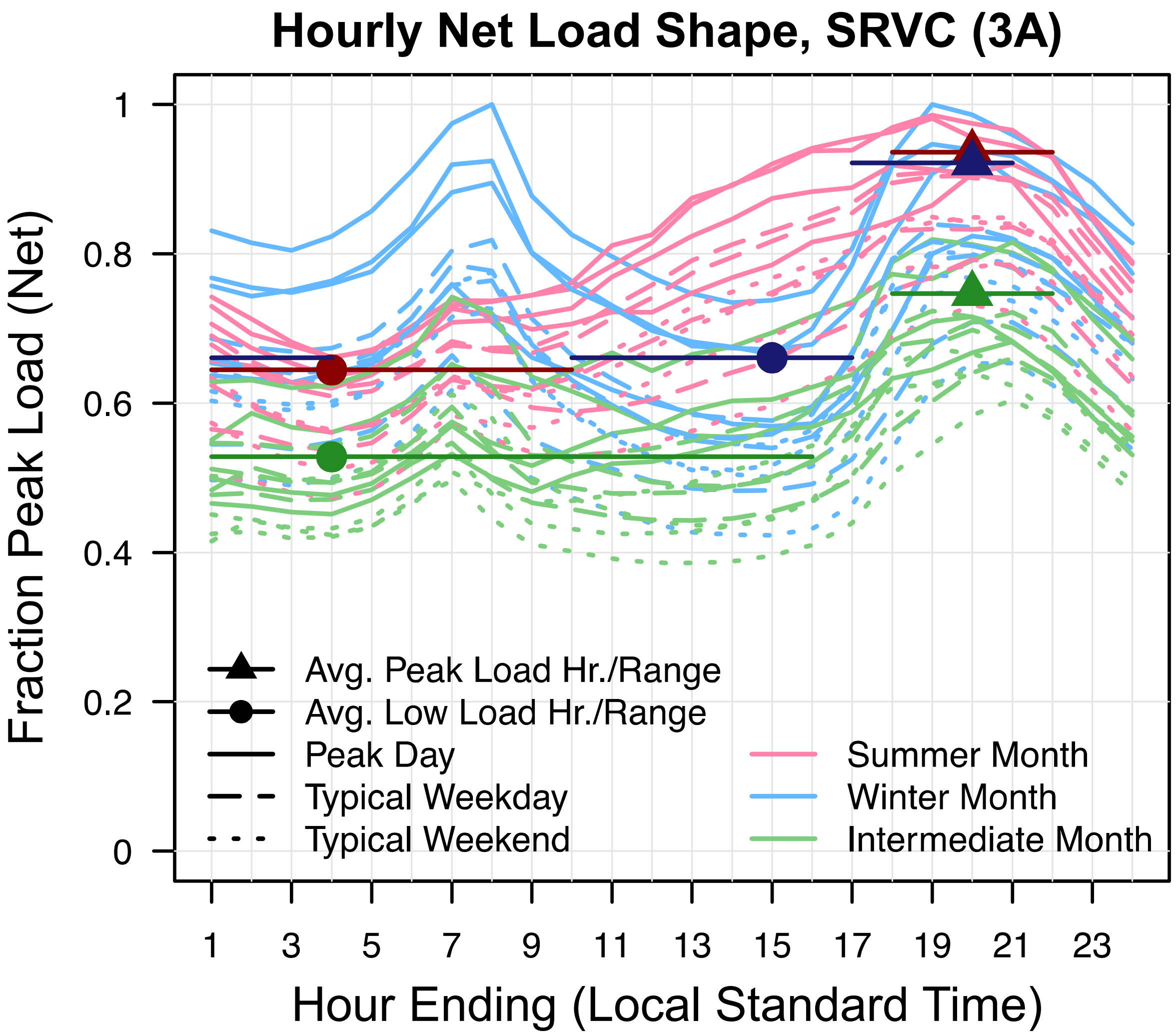
Baseline and measure operations vary by building type, end use, climate location, and electricity system parameters



The highest and lowest net utility system load hour periods are defined by season using EIA system load profiles

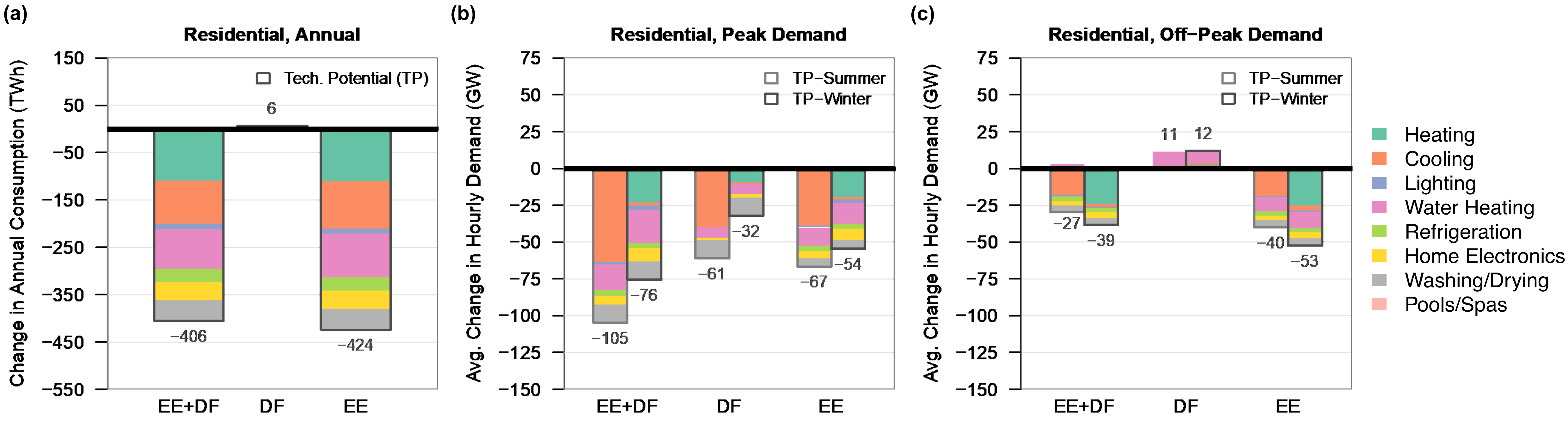
- Regional system load shapes *net of renewable supply* for the year 2050 are used as a reference for measure development (year with the highest renewable penetration levels).

- Flexibility measures are designed to remove load during net peak demand periods and build load during low net demand periods (if possible), flattening the net load shape.



Best available building efficiency and flexibility can avoid up to 406 TWh of annual electricity and 105 GW daily net summer peak demand

Figure 2: **National impacts of best available building efficiency and flexibility measure sets in 2030**



David Siddiqui
Oracle

U.S. DEPARTMENT OF ENERGY

Behavior Change, Efficiency, and Climate

DOE Better Buildings Residential Network Peer Exchange Call

David Siddiqui

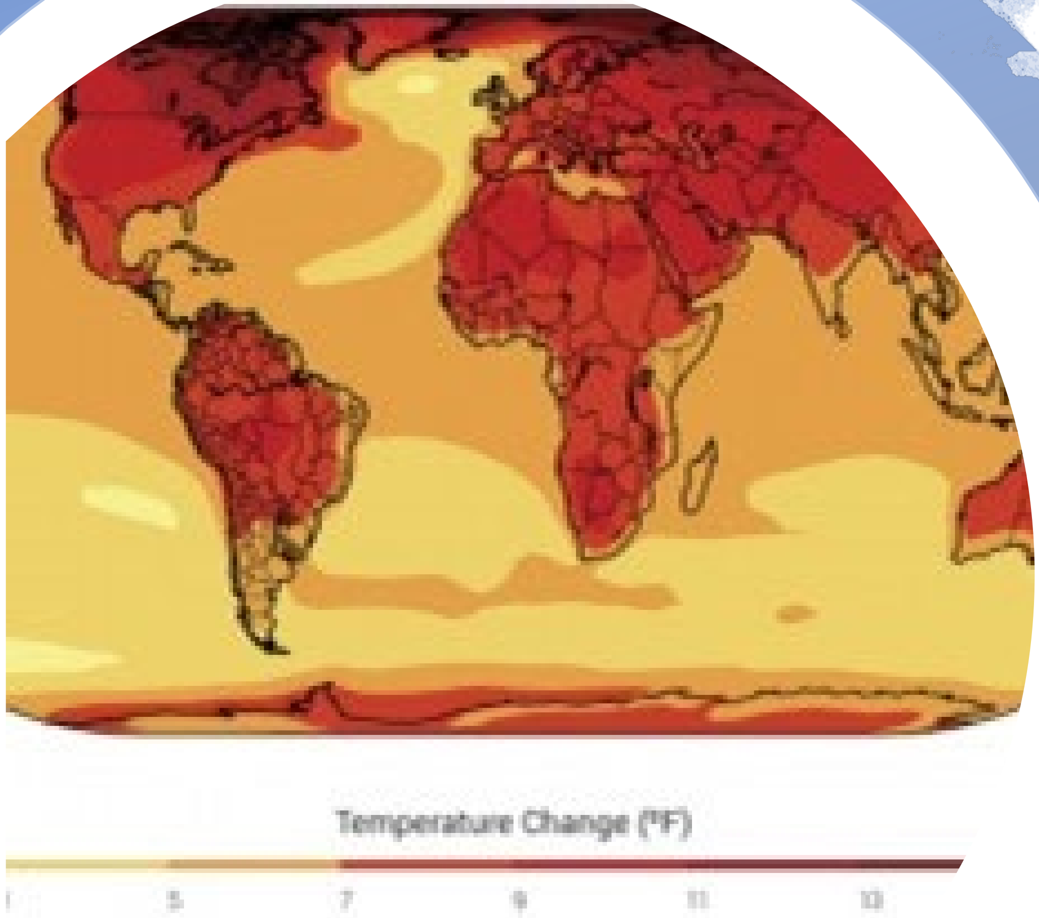
Senior Manager, Regulatory Affairs and Market Development

Opower

September 9, 2021

Safe harbor statement

The following is intended to outline our general product direction. It is intended for information purposes only, and may not be incorporated into any contract. It is not a commitment to deliver any material, code, or functionality, and should not be relied upon in making purchasing decisions. The development, release, timing, and pricing of any features or functionality described for Oracle's products may change and remains at the sole discretion of Oracle Corporation.



Nearly the entirety of the scientific community agrees that in order to avoid catastrophic climate change impacts, we must cut GHG emissions well before 2030.

Time is not on our side.

Getting to net zero utility emissions

CLEAN ENERGY SUPPLY	ENERGY EFFICIENCY	DEMAND FLEXIBILITY	BENEFICIAL ELECTRIFICATION
Replace carbon-intense energy supply with non-emitting sources: wind, solar, RNG, hydrogen, etc.	Reduce emissions quickly and affordably with efficient equipment, building upgrades, and behaviors	Shift demand to when supply is clean and inexpensive with smart price signals and real-time DER automation	As supply becomes cleaner, convert transportation, heat, and industries to electricity for the energy they need

EQUITY & AFFORDABILITY

Provide equitable access to clean energy solutions and ensure limited-income customers don't get stuck with the cost of a more expensive energy system

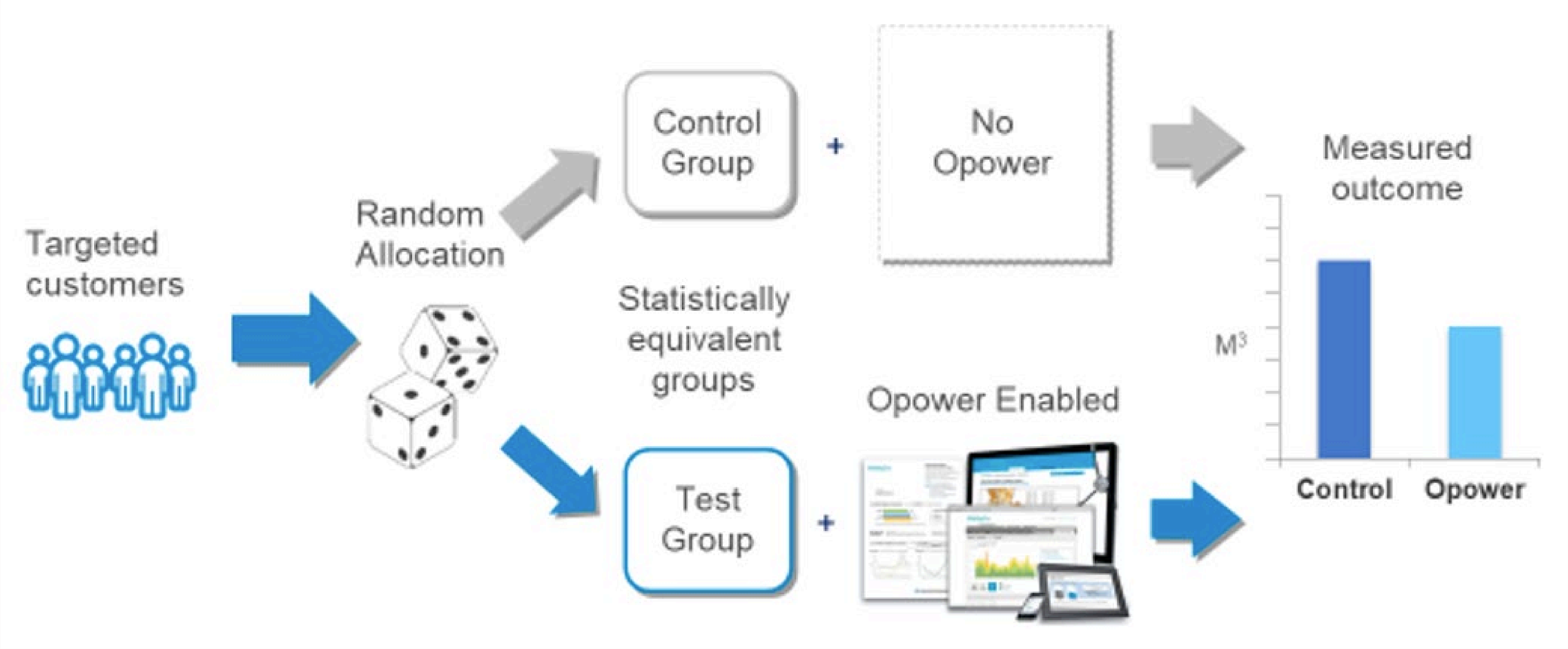
The Opower Customer Engagement Platform

ENERGY EFFICIENCY | PEAK MANAGEMENT | LOAD SHAPING & RATES | PROACTIVE ALERTS | DIGITAL SELF SERVICE | CONNECTED HOMES | SMART METER ENGAGEMENT | DER ENGAGEMENT | CALL CENTER INTERFACE

ANALYTICS VISUALIZATION AND DISCOVERY

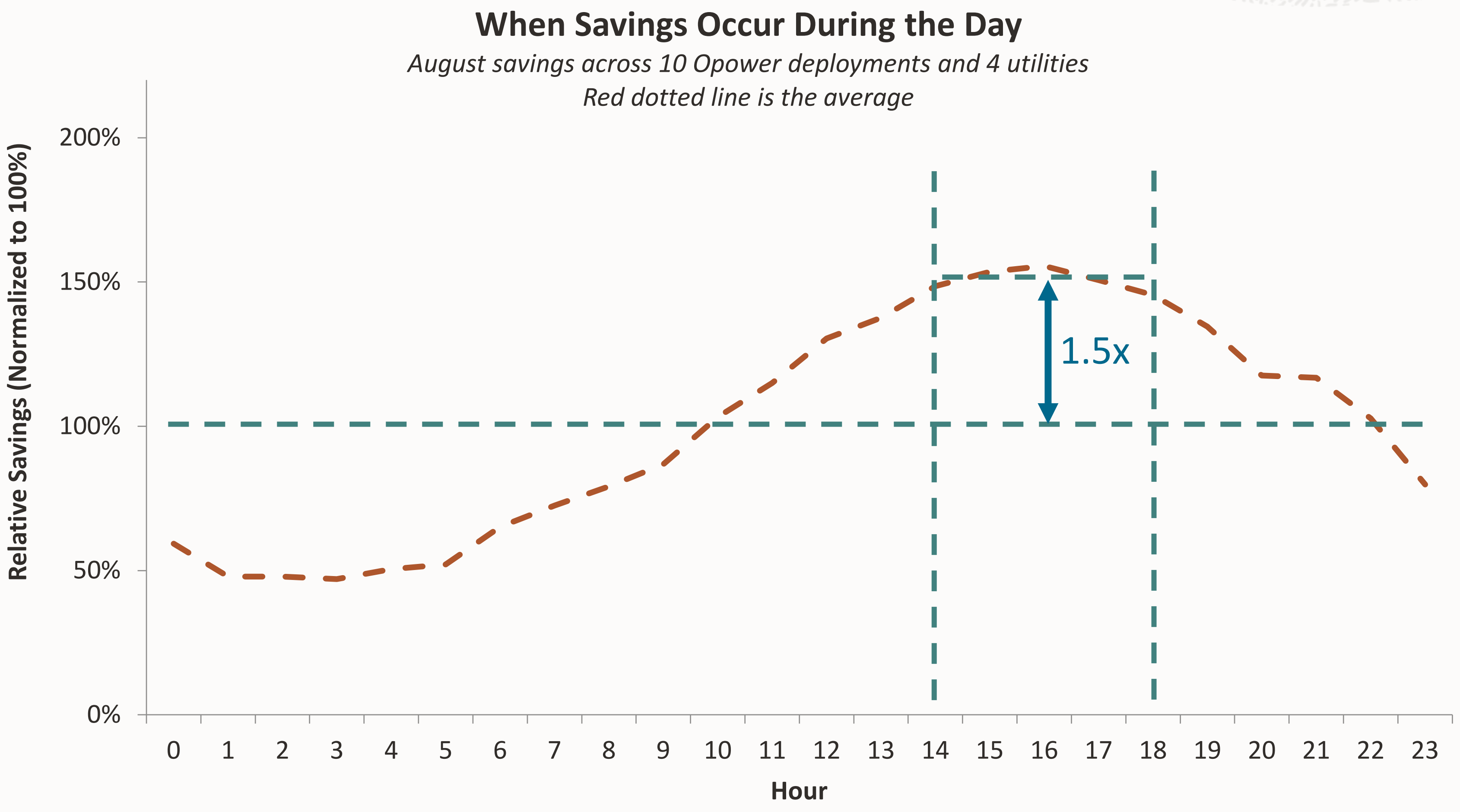
ENTERPRISE GRADE INTEGRATIONS | APPLIED DATA SCIENCE | ENERGY DISAGGREGATION | DYNAMIC SEGMENTATION & MARKETING | BEHAVIORAL SCIENCE | USER-CENTERED DESIGN

Randomized Controlled Trial (RCT) Ensures Accurate Measurement



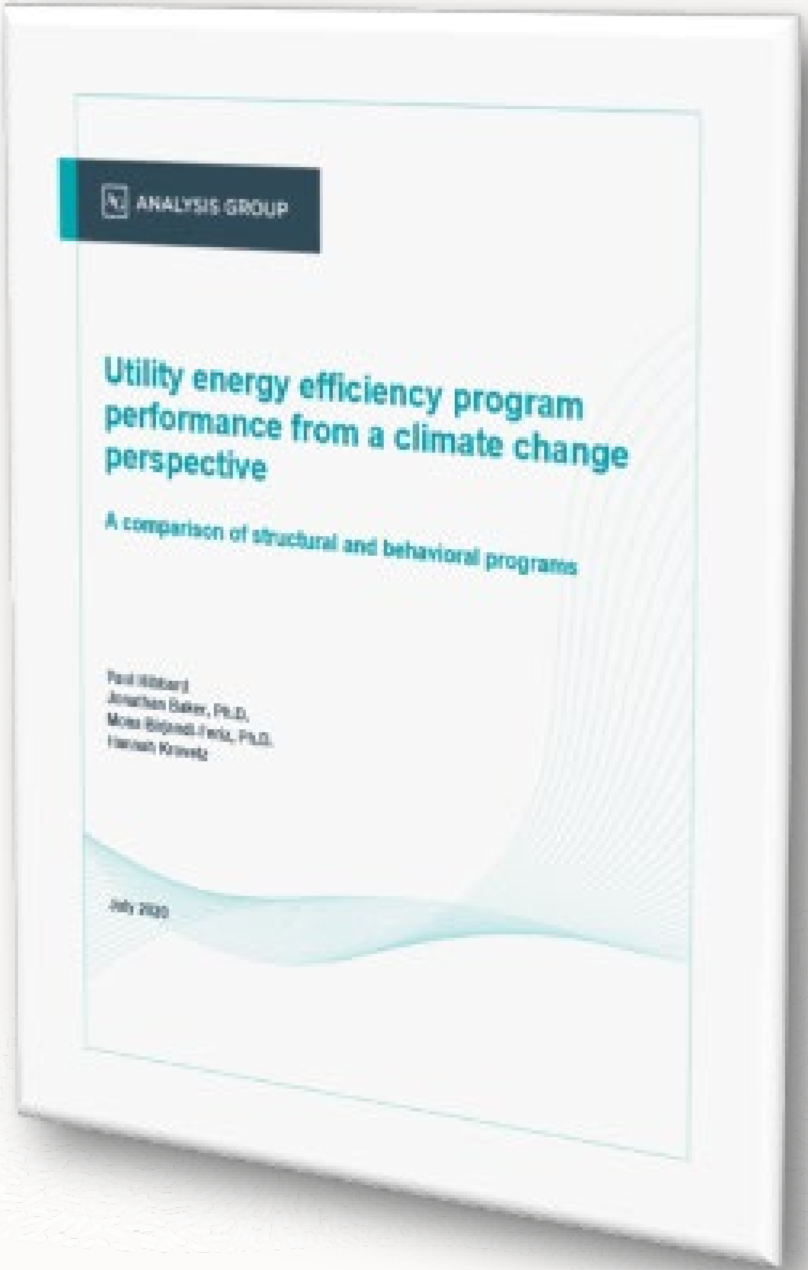
Opower's EE solutions produce greater energy savings during peak hours

Savings are, on average,
1.5x
higher during peak hours of the hottest months



Analysis Group Research: Analyzing the climate impacts of EE programs

- First-of-its-kind research
- Examined two types of EE programs: behavioral and structural
- States included:
  - Maryland (BGE)
  - Illinois (ComEd)
  - Massachusetts (National Grid)
  - New York (ConEd, behavioral only)



Analysis Group Research: Approach

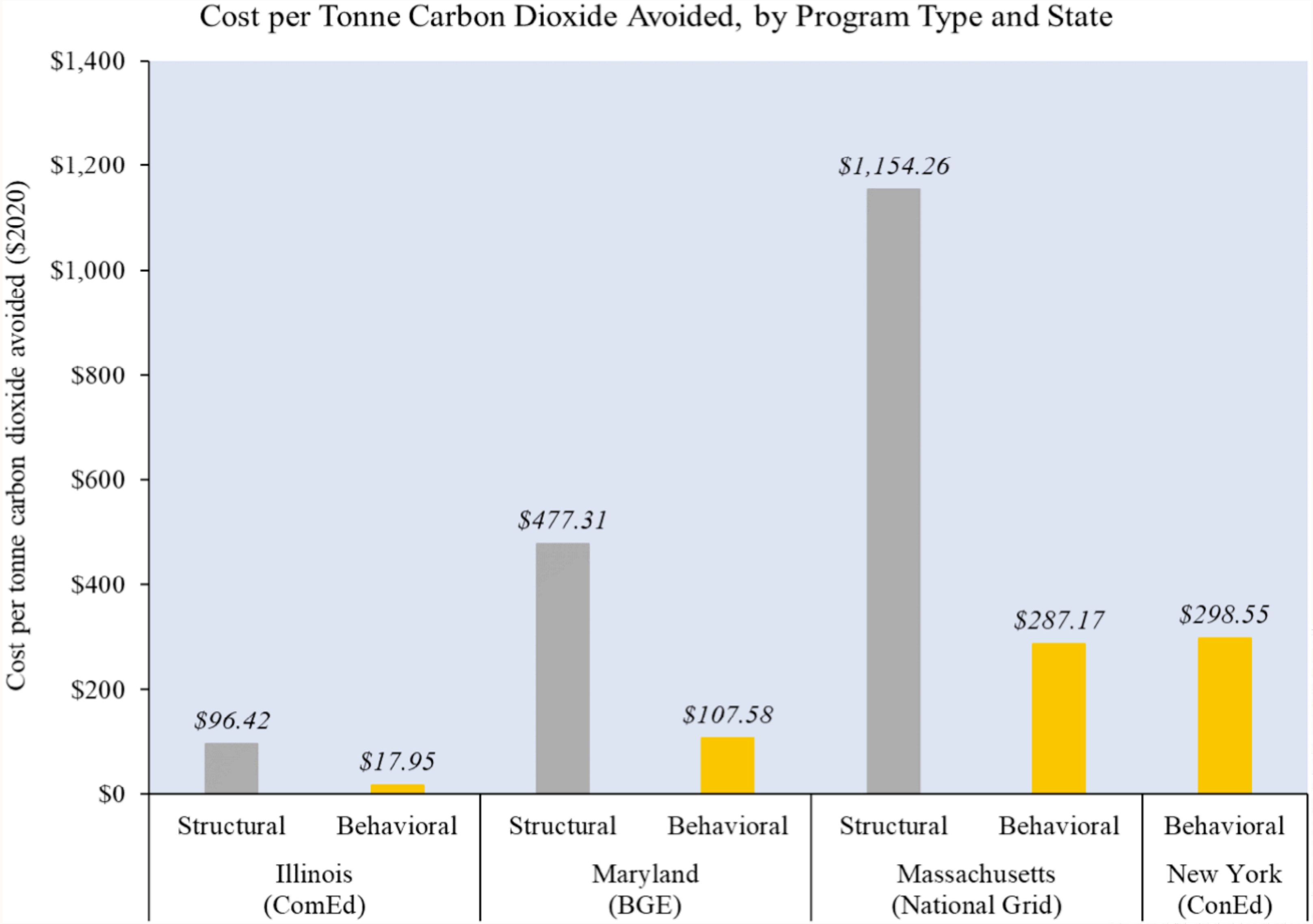
Premise: A ton of carbon avoided today is worth more than a ton avoided in the future.

Hypothesis: Behavioral EE, even if short-lived, has a significant impact on achieving climate goals.

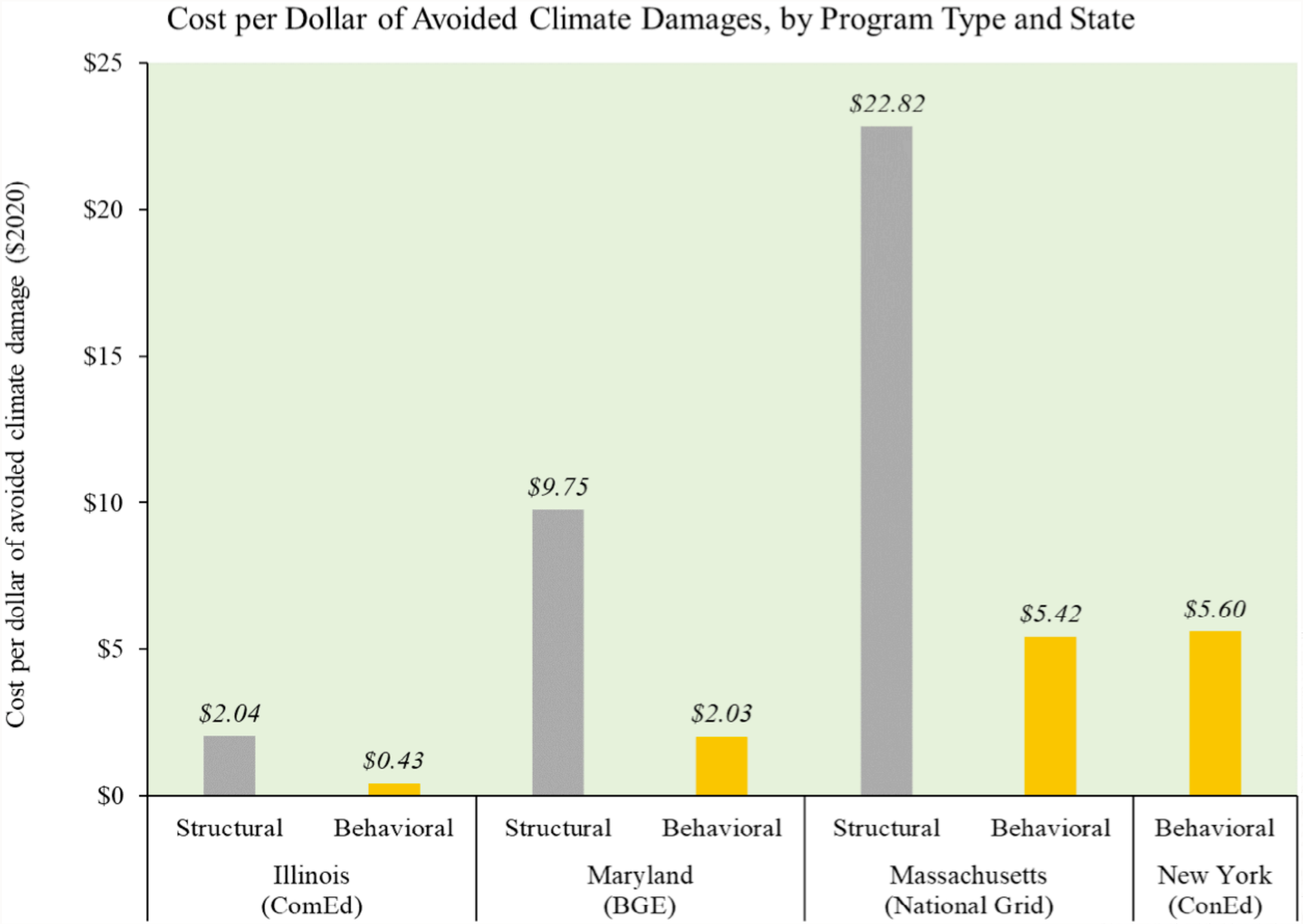
Analysis: Compare behavioral and structural EE programs in terms of:

- Cumulative lifetime electric savings
- Cumulative avoided CO_2 emissions
- Cost per tonne of avoided CO_2 emissions
- Cumulative avoided climate damages
- Cost per dollar of avoided climate damages
- Number of participants

Analysis Group Research: Results



Analysis Group Research: Results



Analysis Group Research: Maryland Data

Summary Comparison of Structural and Behavioral Energy Efficiency Programs

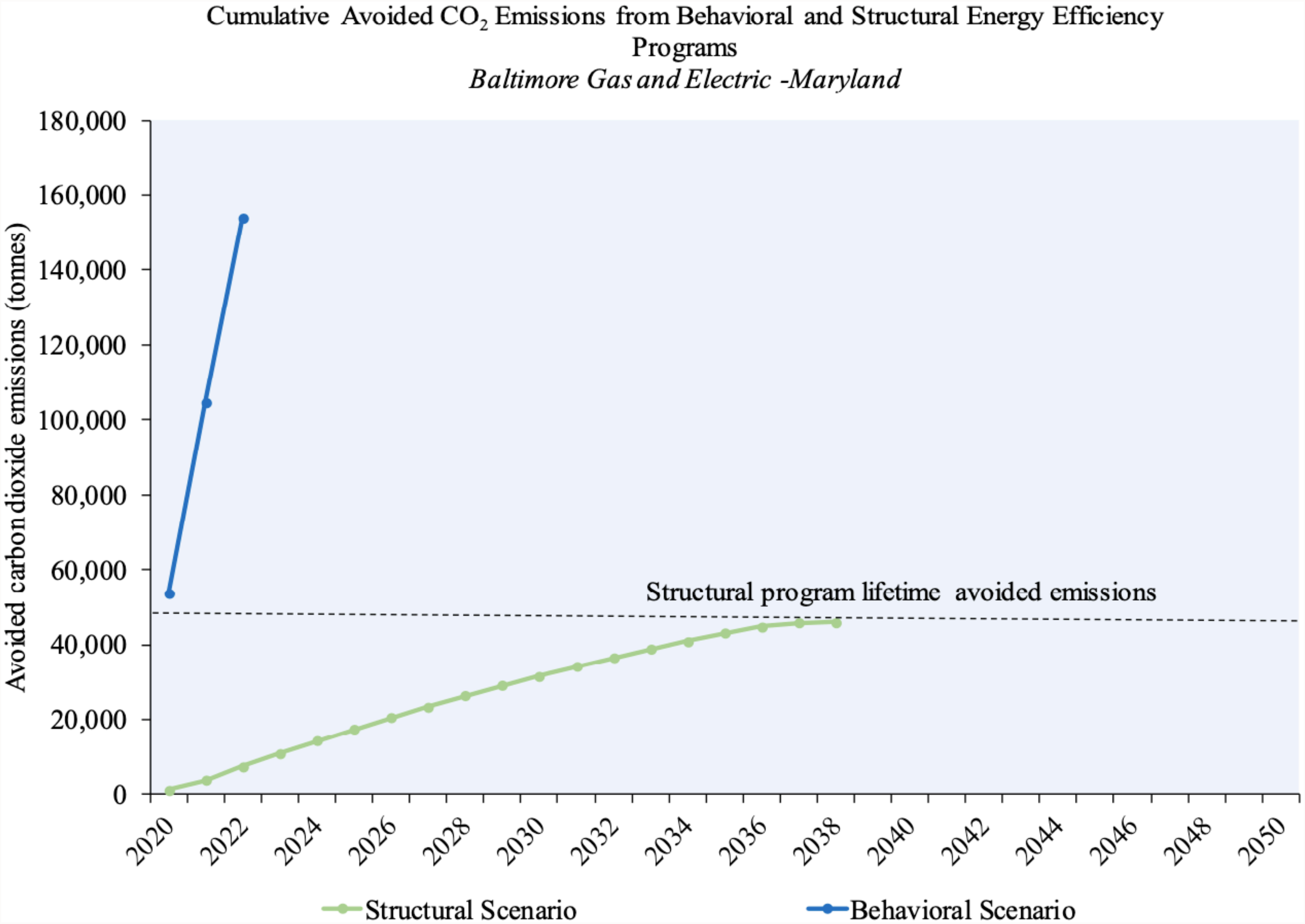
Baltimore Gas and Electric - Maryland

Parameter	Structural	Behavioral
Cumulative Electricity Savings (MWh)	166,650	415,022
Cumulative avoided CO_2 emissions (tonnes)	45,942	153,885
Cumulative avoided climate damages	$2,249,495	$8,151,269
Number of Participants	18,300	902,900
Cost per tonne CO_2 avoided	477.31	107.58
Cost per dollar of avoided climate damage	$9.75	$2.03

Notes:

[1] Costs represent total resource costs in $2020.

Analysis Group Research: Maryland Data



Analysis Group Research: Findings

- BEE delivers climate benefits at a fraction of the cost of SEE.
- While individual customer savings may be lower for BEE, the total annual and total cumulative savings for BEE are higher due to the scale at which BEE programs operate.
- Continued administration of BEE programs achieve the same reduction of CO2 emissions as SEE programs but approximately five times faster.
- Timing matters - taking steps to achieve GHG emission reductions sooner and faster is becoming vastly more important.
- BEE programs are one of the few utility-supported measures that benefit a broad reach of residential consumers.
- Behavioral and structural programs complement each other and work better together than in isolation.

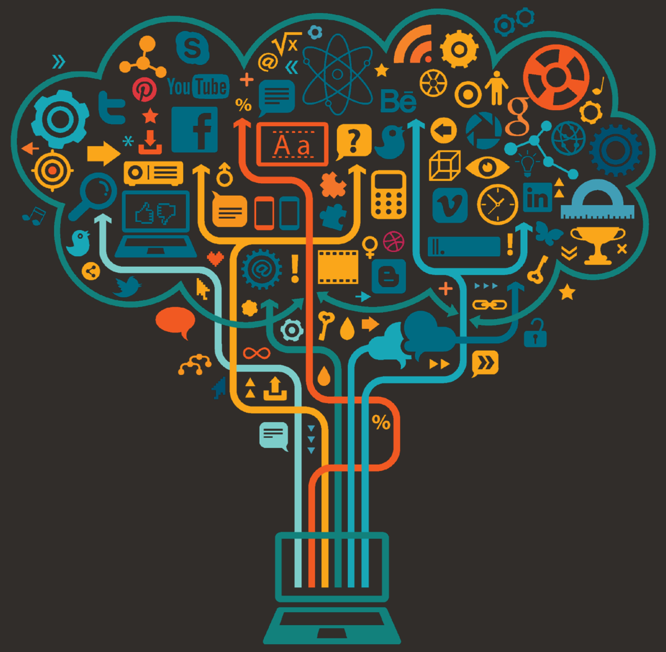
Analysis Group Research: Policy Recommendations

1. Consider GHG metrics and the timing of GHG reductions in the planning, budgeting, and evaluation of EE programs.
2. Pursue all cost-effective energy efficiency.
3. Maintain annual energy savings goals (rather than lifetime) to capture the time component of avoided GHG emissions.
4. Adopt performance incentives that reward utilities for cost-effective energy savings and rapid GHG emissions reductions.
5. Promote joint design and administration of behavioral and structural programs.


ORACLE

Oracle Utilities Mission for the Oracle Industries Innovation Lab

Create a physical space to allow diverse participants and stakeholders to explore, collaborate on, prototype, and create innovative solutions for utilities to thrive in a sustainable and rapidly changing future




FAILE


2:10

Thank you

David Siddiqui
+1 510 908 4092
david.siddiqui@oracle.com

Reuven Sussman, Ph.D.

ACEEE

U.S. DEPARTMENT OF ENERGY

Behavior Change: Assumptions Vs Reality

Dr. Reuven Sussman

Director, Behavior and Human Dimensions Program

American Council for an Energy-Efficient Economy

American Council for an Energy-Efficient Economy

Better Buildings Peer Exchange Call:
September 9, 2021

Never Assume

- Start by asking a few questions
  - **What's been done before?**
  - **What might be different for our specific situation?**
  - **What do we know about how people change?**
- Even after learning this, things don't always go as planned
  - **TEST TEST TEST**

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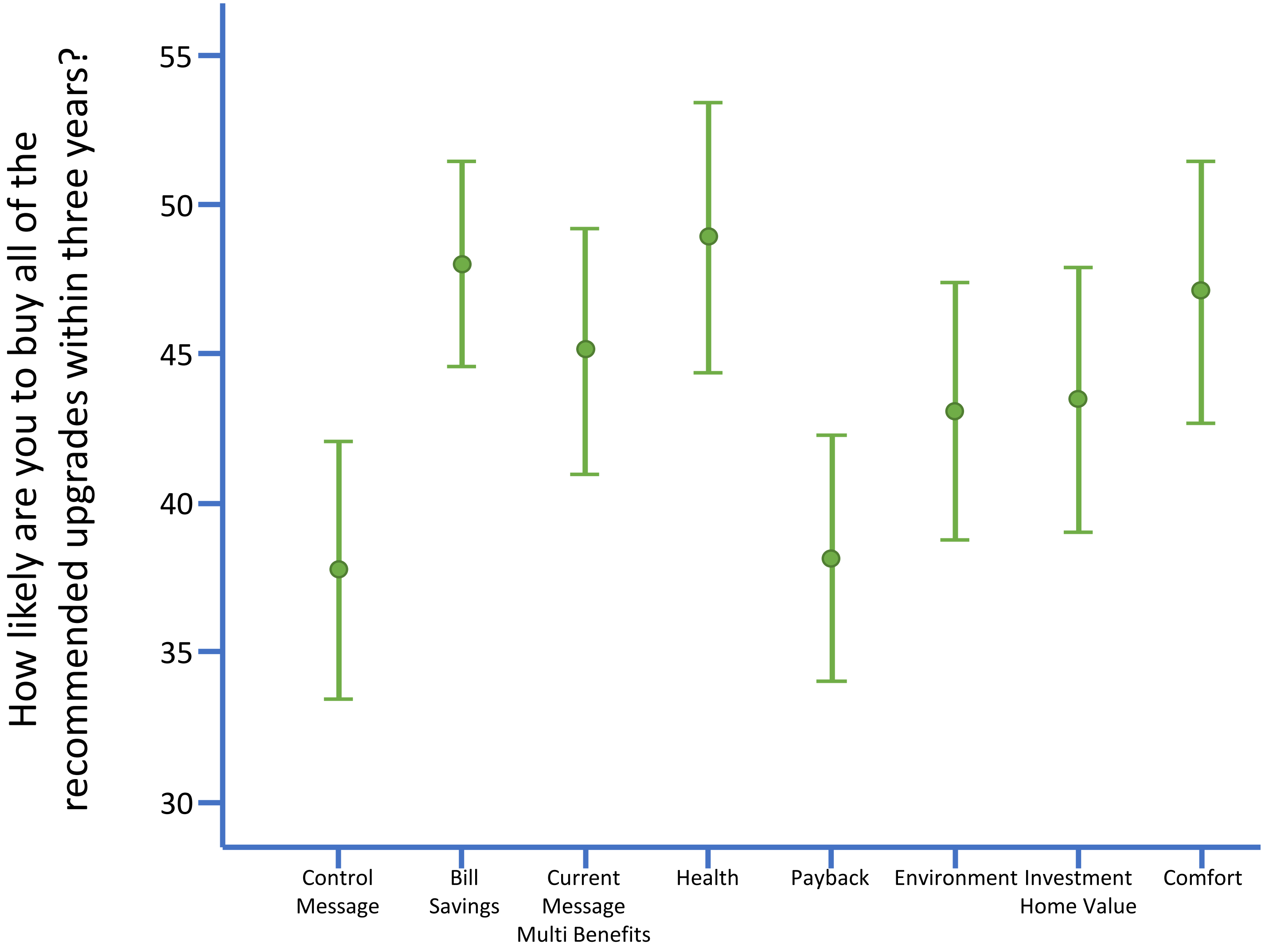
Common Mistake #1: Assuming Motivations

Financial Benefits are Not the Only Thing that Matters (Sussman et al., 2017)

Imagine that you enrolled in the Home Performance with ENERGY STAR program and received a home energy assessment a few days ago. The contractor came to your house, performed diagnostic tests, discussed your needs, and provided a list of actions you could take to upgrade your home. The list of recommendations totaled about $7,500.

- Participants see one of the following benefit messages:
  - Bill savings
  - Health
  - Payback
  - Environment
  - Good investment/increases home value
  - Comfort
  - Current Energy Star message (multi benefits)

Benefits Results Overall



Environmental Motivations Don't Always Work

WASHROOM EMPTY?

CONSERVE ENERGY -

PLEASE TURN OFF THE LIGHTS

TURNING OFF THE LIGHTS FOR EVEN 5 SECONDS SAVES ELECTRICITY, WHICH REDUCES GREENHOUSE GAS EMISSIONS...

AND THAT'S A GOOD THING. THANKS! 🙂

Common Mistake #2: Underestimating Context

Change decisions by changing the frame of reference

Choice architecture (Huber, Payne, Puto, 1982)

Example (Beer)

- Presented like this:
  - **"Below you will find 3 brands of beer. You know only the price per six pack and the average quality ratings made by subjects in a blind taste test. Given that you had to choose one brand to buy on this information alone, which one would it be?"**

Brand	Price/Six pack	Average Quality Rating (0-100)
A	$1.80	50
B	$2.60	70
C	$1.80	40

Choice Architecture (Sussman & Chikumbo, 2017)

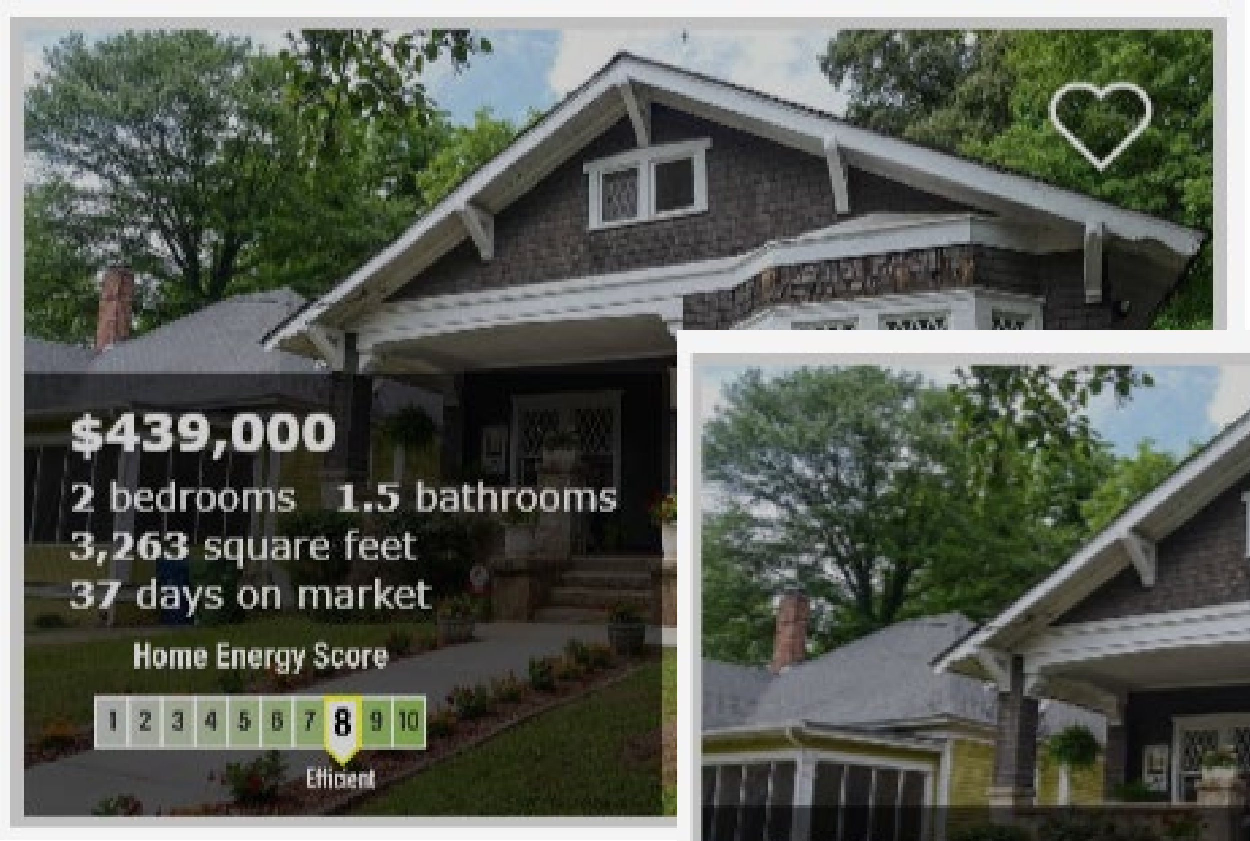
Item	Cost	Annual savings	SIR
Seal Air Leaks	$1,015	$142.43	2.8
Attic Improvements	$1,883	$140.17	2.2
Upgrade and Adjust Thermostat	$170	$197.02	12.7
Upgrade Water Heater	$1,223	$72.75	0.9
Upgrade Lighting	$77	$238.91	21.9
Refrigerator	$1,336	$68.86	0.9

More target items
1.6 vs 1.2

Higher total spending
$4,521 vs $1,760

Item	Cost	Annual savings	SIR
Seal Air Leaks	$1,015	$142.43	2.8
Attic Improvements	$1,883	$140.17	2.2
Upgrade Water Heater	$1,223	$72.75	0.9
Cooling System	$3,355	$183.8	0.8
Heating System	$6,288	$263.68	0.8
Refrigerator	$1,336	$68.86	0.9

Context in Real Estate Energy Labels



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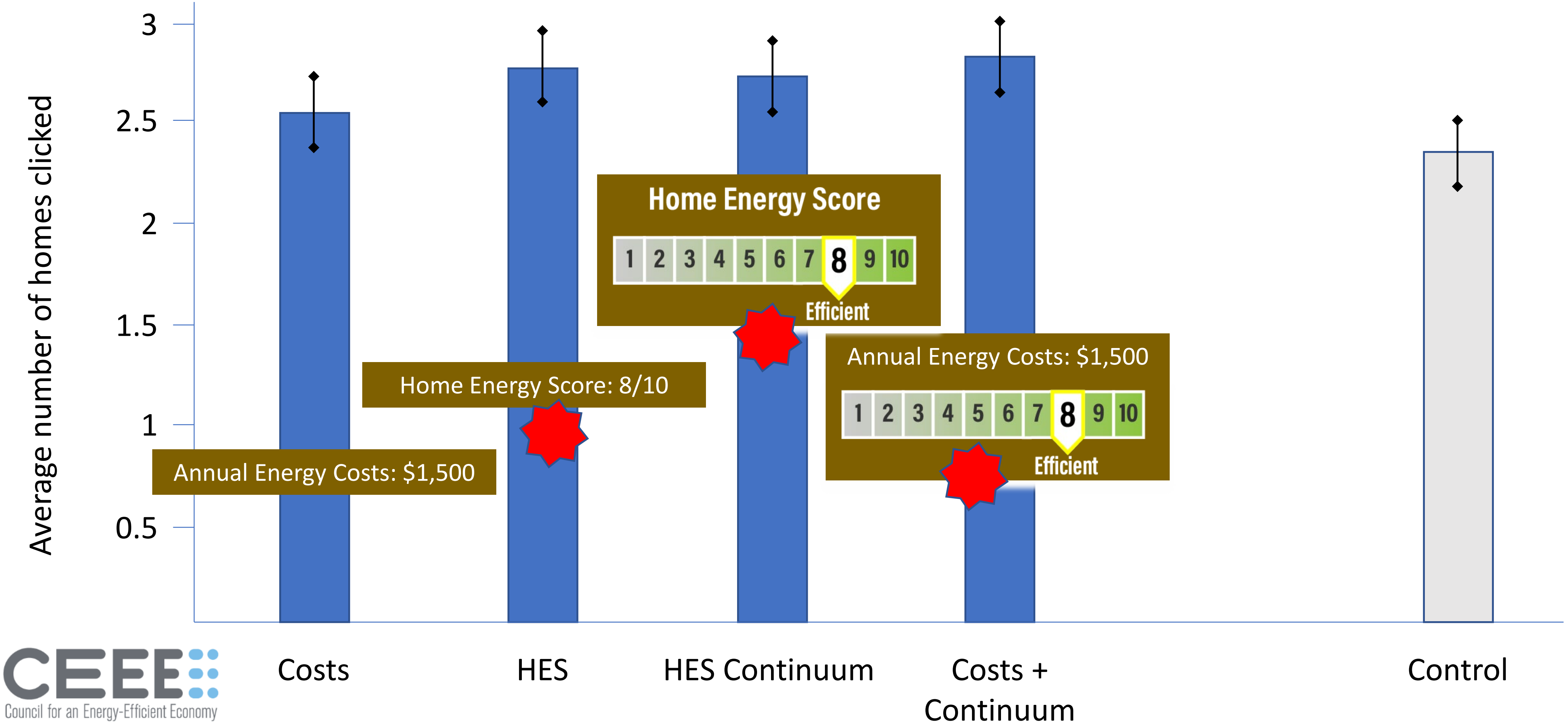
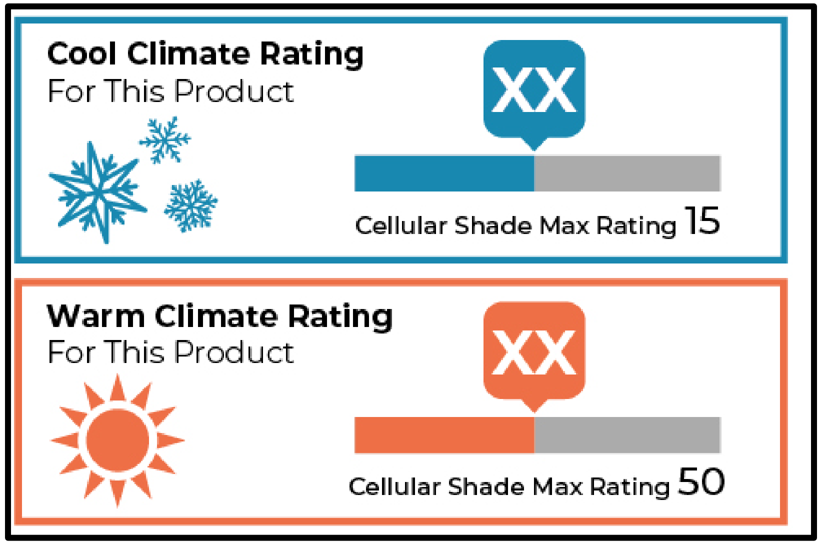
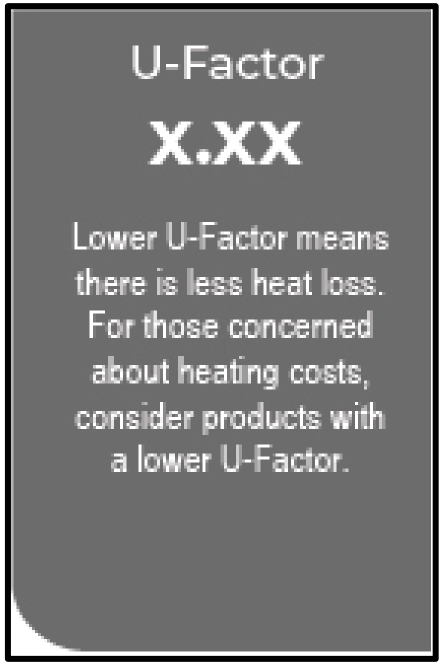
Clicking the most efficient option

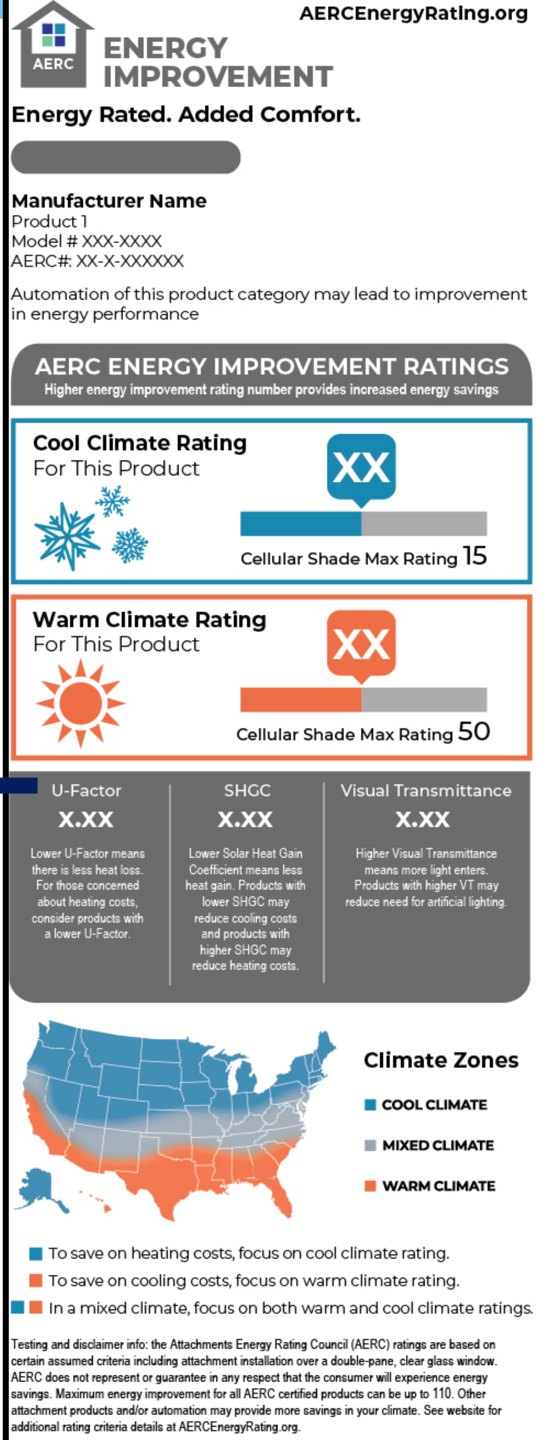


Common Mistake #3: People Just Need More Information

Attachments Energy Ratings Council (AERC) Labels







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How to Avoid Common Mistakes

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How To Design Something That Works

- Figure out the problem, then come up with a solution
- Background research
- Preliminary surveys, interviews and observations
- TEST TEST TEST

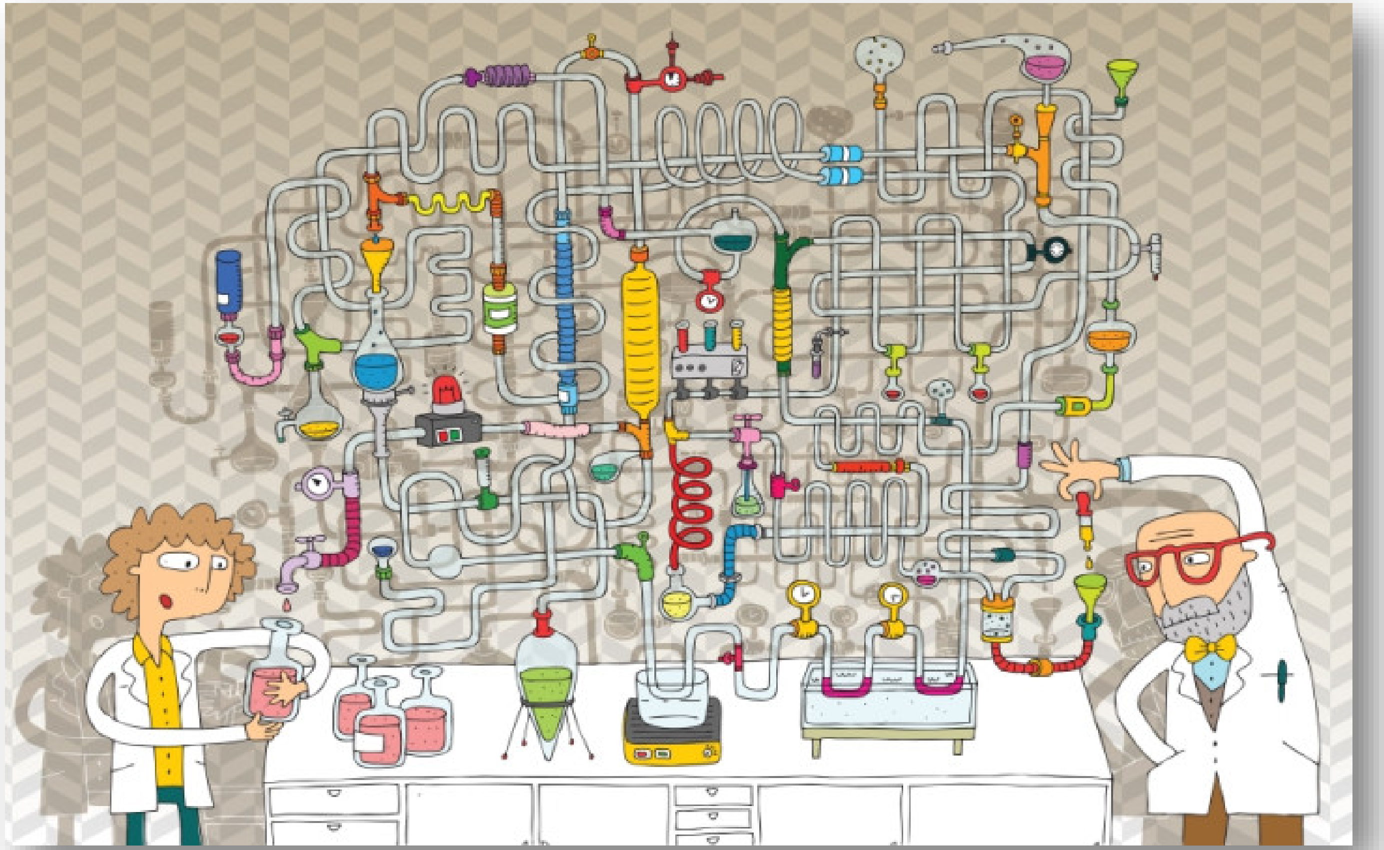

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Photo Credit: Giuseppe Milo

Thank you!

Reuven Sussman, Ph.D., Director, Behavior and Human Dimensions Program, ACEEE, rsussman@aceee.org

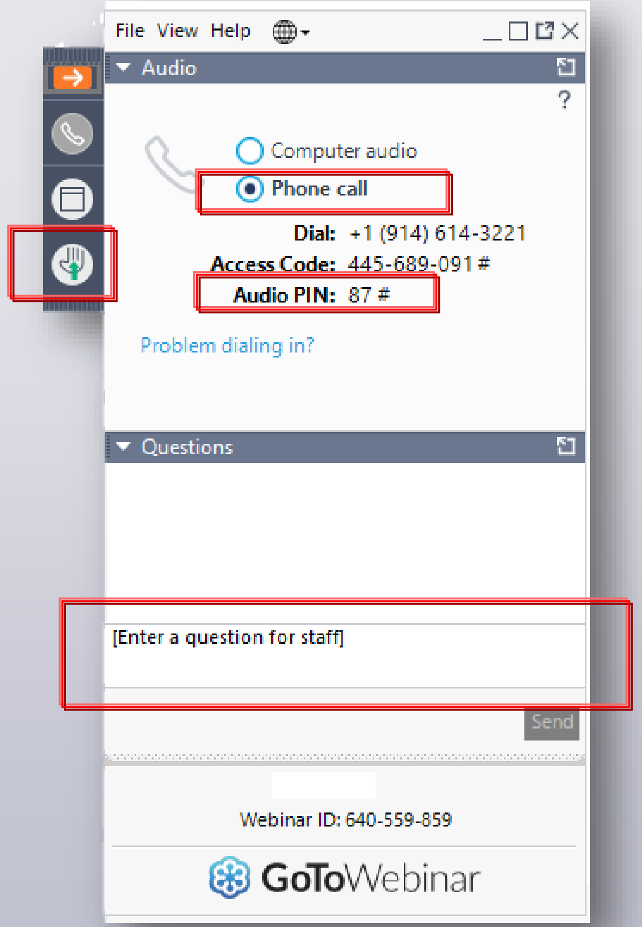
Emma Cooper, M.Sc., Research Analyst, Behavior and Human Dimensions Program, ACEEE

Thank you!

Discussion: Share Your Questions

Open and close your **control panel**

Raise your hand to enter the discussion



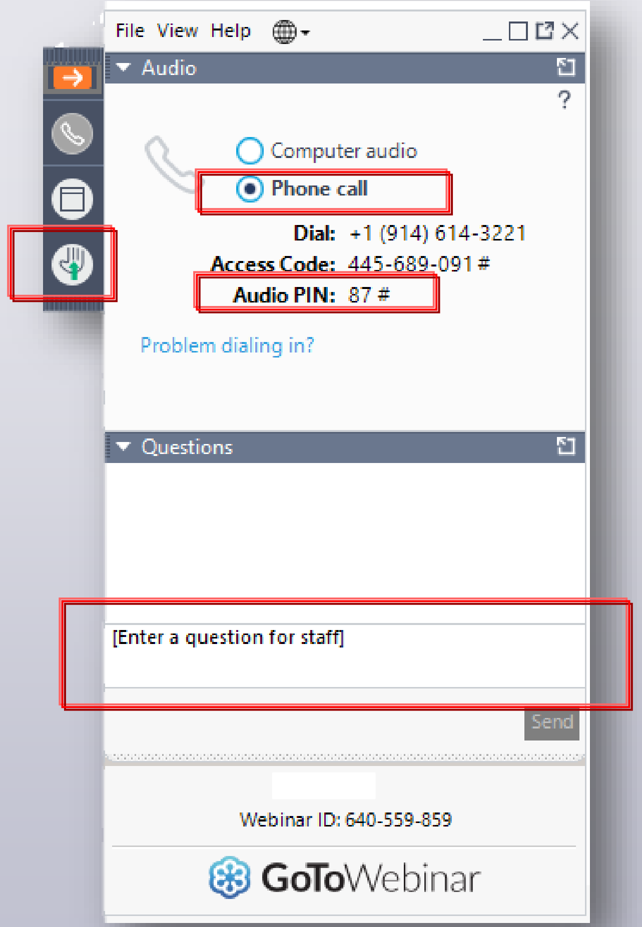
Please use the **questions box** to submit questions, comments, or alert us of technical difficulties

If you have called in on a phone today, double check that you've selected telephone as your audio option.

Open Discussion

Open and close your **control panel**

Raise your hand to enter the discussion



Please use the **questions box** to submit questions, comments, or alert us of technical difficulties

If you have called in on a phone today, double check that you've selected telephone as your audio option.

Closing Poll

- **After today's call, what will you do?**
  - Consider implementing one or more of the ideas discussed
  - Seek out additional information on one or more of the ideas
  - Make no changes to your current approach
  - Other (please explain)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Explore the Residential Program Solution Center

Resources to help improve your program and reach energy efficiency targets:

- Handbooks - explain *why* and *how* to implement specific stages of a program.
- Quick Answers - provide answers and resources for common questions.
- Proven Practices posts - include lessons learned, examples, and helpful tips from successful programs.
- Technology Solutions NEW! - present resources on advanced technologies, **HVAC** & **Heat Pump Water Heaters**, including installation guidance, marketing strategies, & potential savings.

https://rpsc.energy.gov

Thank You!

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